S

ENGINEERING DATA TRANSMITTAL

1. EDT 823606	1A. Page 1 of 2

2. To: (Receiving Organization)	3. From: (Originating Organization)	4. Related EDT No.:
Distribution	WTP Support Technology and Development	N/A
		5. Structure Location: N/A
6. Proj./Prog./Dept./Div.: WTP Support Technology and Development	7. Responsible Engineer/Design Agent: W. Dobson	8. System Designator: N/A
		9. Building No.: N/A
10. Originator Remarks: Initial Release of: WRPS Technology Development Roadmap		11. Equipment ID No. (EIN): N/A
		12. Permit/Permit Application No.: N/A
13. USQ No.: ☒ N/A Date:	13(A). TBDs or HOLDs In the Data Transmitted? ☐ Yes ☒ No	15. Purchase Order No.: N/A
14. PrHA Screening No.: ☐ N/A PrHA-01415 Rev. 0	13(B). Project Number or Identifier: N/A	16. Required Response Date: N/A

17. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Hard-copy or PDF	(G) Approval Desig-nator	(H) Reason for Trans-mittal	(I) Origi-nator Dispo-sition	(J) Receiv-er Dispo-sition
1	RPP-PLAN-43988	All	0	WRPS Technology Development Roadmap	H	N/A	1	1	1

18. IMPACTED DOCUMENTS – NON ENGINEERING

Type of Document	Document Number
None	

19. IMPACTED DOCUMENTS – ENGINEERING

Type of Document	Document Number
None	

20. KEY

Approval Designator (G)	Reason for Transmittal (H)	Disposition (I)
See TFC-ENG-DESIGN-C-25	1. Approval 2. Review 3. Distribution	1. Approved 2. Approved w/comment 3. Reviewed no comment 4. Reviewed w/comment 5. Disapproved

21. SIGNATURE/DISTRIBUTION

(H) Reason	(I) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
1,3	1	Originator MJ Faries	Marcus Faries	5/25/10	B1-55
1,3	1	Resp. Engr. W Dobson	W Dobson	05/25/10	~~R1-01~~ EC-30
1,3	1	Resp. Mgr. RE Mendoza	[signature]	5-25-10	B1-55
		QA N/A			
		IH&S Engr. N/A			
		Env. Engr. N/A			
1,3	1	JA Edge	Jim A Edge	25/5/2010	B1-55
1,3	1	TL Sams	T L Sams	5/25/10	B1-55
3		See Attached Distribution Sheet			

(H) Reason	(I) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN

22. DOE APPROVAL (if required)

Ctrl. No.

23. Release Date/Station/ID MAY 26 2010

STA: 15

65

BD-7400-172.2 (REV 2)

DISTRIBUTION SHEET

To	From	
Release Station	WTP Support Tech. and Development	Page 2 of 2
Project Title/Work Order		Date 21 May 2010
WRPS Technology Development Roadmap		EDT No. 823606
		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
NW Kirch	R2-58	X			
TW Crawford	B1-55	X			
MS Gerber	B1-55	X			
MN Wells	B1-55	X			
PJ Certa	B1-55	X			
PL Rutland	B1-55	X			
SA Saunders	S7-83	X			
C Burrows	B1-55	X			
KA Colosi	E6-30	X			
WB Barton	S7-90	X			
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GL Dunford	B1-55	X			
DH Shuford	B1-55	X			

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WRPS Technology Development Roadmap

T. L. Sams
R. E. Mendoza
J. A. Edge

Washington River Protection Solutions, LLC
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-08RV14800

EDT/ECN: EDT-823606 UC:
Cost Center: Charge Code:
B&R Code: Total Pages: 53

Key Words: Technology development, roadmap, WTP, Transformational Technology

Abstract: The WRPS Technology Development Roadmap document is a tool for WRPS management, DOE, EM, NAS, and others to understand the risks and technology gaps associated with the successful completion of the River Protection Project (RPP) mission, and where timely technology development can have the greatest impact to reduce those risks and uncertainties.

MAY 26 2010
DATE:
STA: 15
HANFORD RELEASE
ID: 65

Nancy A Fouad 5-26-10
Release Approval Date

Release Stamp

Approved For Public Release

EXECUTIVE SUMMARY

The current revision of ORP-11242, *River Protection Project System Plan*, Revision 4 (referred to as SP4 in this document), establishes a strategy to complete the River Protection Project (RPP) mission that includes tank waste retrievals, waste processing, and tank closures. SP4 identifies a baseline case scenario as well as "success criteria," a limited number of near and long-term milestones that serve as proxies for future approved milestones. In addition to outlining the methods required to meet the mission schedule and success criteria dates, the Technology Development Roadmap (TDR) discusses numerous strategies that are being investigated to accelerate mission completion.

In addition to identifying the technology gaps and solutions, this TDR identifies the specific RPP mission milestones that drive these technology development activities. Technology gaps are the shortfalls in available knowledge or technology that could prevent the U.S. Department of Energy (DOE) from accomplishing cleanup tasks within expected schedules and/or budgets.

Identification of these gaps and the solutions available to address them are critical to completing the RPP mission and enhancing its safety, effectiveness, and efficiency. While identifying and addressing the technology gaps may not always fully mitigate the risks inherent with technology development, it does minimize those risks and give an early warning to critical path issues. To reduce the technical risk and uncertainty in the RPP mission, this document helps identify the technologies that need to be developed and when they need to be inserted into the evolving cleanup efforts.

The Washington River Protection *Solutions*, LLC (WRPS) Waste Treatment and Immobilization Plant (WTP) Support Technology and Development organization is guided by this TDR to implement the selected technologies and cost effectively optimize program performance within applicable constraints imposed by the RPP mission. The intent is to focus on near-term (1 to 10 years) issues. However, long term (>10 years) issues are not being neglected as planning efforts need to consider the entire RPP mission duration. This TDR will be updated on a recurring basis to incorporate the results of technology development activities, and to incorporate the latest customer priorities and budgetary guidance.

This document addresses the full scope of the RPP mission, including waste storage, retrieval, treatment, and disposal. It targets solutions not only for the operations needed within the tank farms to provide waste feed to the WTP, but also for potential improvements and enhancements to the WTP operations.

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LIST OF TERMS

Terms

Roadmapping is a planning process to help identify scientific and technological capabilities needed for both project and program-level cleanup efforts for the DOE sites.

Technology Solution encompasses equipment, processes, or approaches that potentially can be used to attain a mission goal.

Technology Gap represents a shortfall in available knowledge or technology that could prevent the U. S. Department of Energy from accomplishing a cleanup task on its expected schedule and/or budget.

Transformational technology is a technological breakthrough that could substantially mitigate risk, reduce cost, or accelerate schedule.

Abbreviations and Acronyms

ARF	Aluminum Removal Facility
CCIM	Cold Crucible Induction Melter
CH-TRU	Contact-Handled Transuranic Waste
CSL	Continuous Sludge Leaching
DOE	Department of Energy
DST	Double Shell Tank
ECR	Electro-chemical Caustic Recovery
EM-31	U.S. Department of Energy, Office of Environmental Management
ETF	Effluent Treatment Facility
FBSR	Fluidized Bed Steam Reformer
FY	Fiscal Year
HLW	High Level Waste
ICD	Interface Control Document
IDF	Integrated Disposal Facility
JHCM	Joule-Heated Ceramic Melter
LAW	Low Activity Waste
MAR	Mission Analysis Report
MARS	Mobile Arm Retrieval System
MYPP	Multi-Year Program Plan
N/A	Not Applicable
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act
ORP	Office of River Protection
PBI	Performance-Based Incentives
PMB	Performance Measurement Baseline
RH-TRU	Remote-Handled Transuranic Waste
RMF	Rotary Micro-Filtration
RMP	Risk Management Plan

RPP	River Protection Project
SCIX	Small Column Ion Exchange
SRS	Savannah River Site
SST	Single Shell Tank
TBD	To Be Determined
TDD	Technology Development and Deployment
TDR	Technology Development Roadmap
TOC	Tank Operations Contractor
TPA	Tri-Party Agreement
WFD	Waste Feed Delivery
WFE	Wiped-Film Evaporator
WP	Waste Planning
WRPS	Washington River Protection Solutions, LLC
WTP	Waste Treatment and Immobilization Plant

1.0 INTRODUCTION

Approximately 57 million gallons of radioactive and hazardous waste are contained in Hanford's aging single shell tanks (SSTs) and double shell tanks (DSTs). The River Protection Project (RPP) mission is to safely and cost effectively retrieve, process, and immobilize tank waste, and subsequently close the tank farms to reduce environmental risk. The Department of Energy (DOE) has hired Washington River Protection Solutions (WRPS) LLC to perform the RPP mission in the Tanks Operations Contract (TOC). The RPP mission encompasses numerous unique challenges; many that will require new technologies to support successful cleanup efforts. In addition to outlining the methods required to meet the mission schedule, several strategies for accelerating mission completion are being investigated and are discussed in this TDR.

This TDR's purpose is to identify technology gaps and the links to RPP mission milestones or goals that drive technology development activities to complete the RPP mission successfully. Technology gaps are the shortfalls in available knowledge or technology that could prevent the DOE from accomplishing cleanup tasks within expected schedules and/or budgets. Identification of these gaps and the solutions available to address them is critical to completing and enhancing the safety, effectiveness, and efficiency of the RPP mission. While identifying and addressing the technology gaps may not always fully mitigate the risks inherent with technology development, it does minimize those risks and give an early warning to critical path issues.

This document includes the full scope of the RPP mission, including waste storage, retrieval, treatment, and disposal. This includes not only the operations needed within the tank farms to provide waste feed to the Waste Treatment and Immobilization Plant (WTP), but also to potentially improve and optimize the WTP operations.

2.0 BACKGROUND

In early 2007, the DOE, Office of Environmental Management (EM-31) turned to the National Academy of Sciences (NAS) for assistance in preparing a congressionally requested engineering and technology roadmap to support the cleanup effort by performing a gap analysis on DOE's cleanup effort. Subsequent to the gap analysis EM published the DOE 2008a, "Engineering and Technology Roadmap – Reducing Technical Risk and Uncertainty in the EM Program" and DOE 2008b, "Waste Processing Multi-Year Program Plan Fiscal Year 2008-2012," which documented EM's strategy to close the gaps across the DOE complex. The NAS later issued a report entitled NAS 2009, "Advice on the Department of Energy's Cleanup Technology Roadmap – Gaps and Bridges" that identified science and technology gaps, with priorities, for DOE's waste processing program areas. Table 1 summarizes the NAS identified gaps for the waste processing area.

Table 1. National Academy of Sciences Technology Development Gaps

NAS Waste Plan (WP) Gap Number	Statement of Gap	NAS Priority
WP-1	Substantial amounts of waste may be left in tanks/bins after their cleanout – especially in tanks with obstructions, compromised integrity, or associated piping.	High
WP-2	Low-activity streams from tank waste processing could contain substantial amounts of radionuclides.	Medium
WP-3	New facility designs, processes, and operations usually rely on pilot-scale testing with simulated rather than actual wastes.	Medium
WP-4	Increased vitrification capacity may be needed to meet schedule requirements of EM's high level waste to be disposed of.	High
WP-5	The baseline tank waste vitrification process significantly increases the volume of high level waste to be disposed.	Medium
WP-6	A variety of wastes and nuclear materials do not yet have a disposition path.	Low

Note: Table taken from the National Academy of Sciences (NAS) document, "Advice on the Department of Energy's Cleanup Technology Roadmap – Gaps and Bridges," NAS 2009.

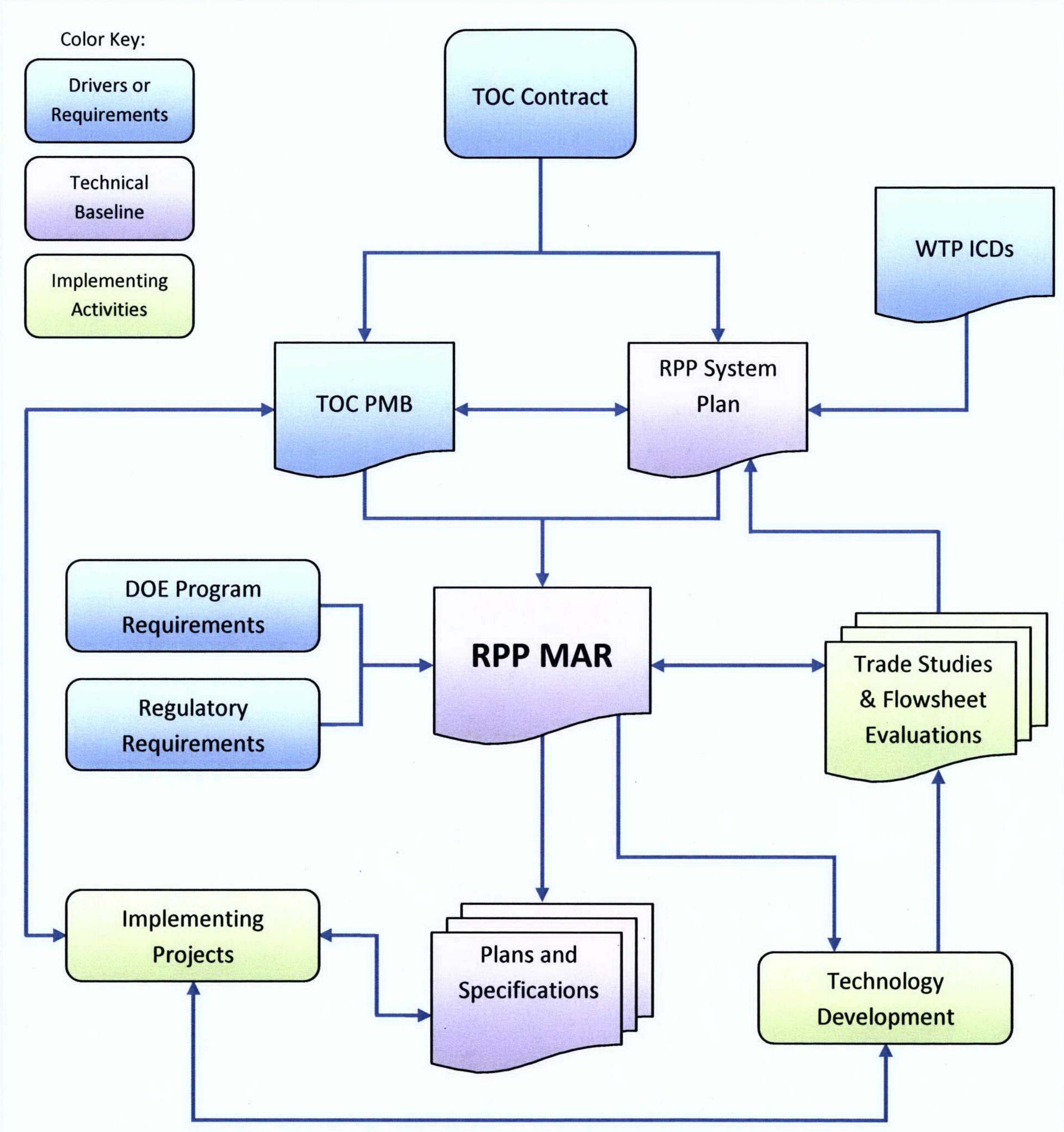
Specific to the RPP mission, multiple documents address technology shortfalls and development needs. These documents include:

- TFC-PLN-39, "*Risk Management Plan*," which describes the systematic process used to assess and manage project risks/opportunities and their potential solutions.
- ORP-11242, *River Protection Project System Plan* (the current Revision 4 is referred to as SP4 in this document), which is the technical baseline for the Performance Measurement Baseline (PMB), and provides a basis for aligning project cost, scope and schedule from upper-tier documents to facility-specific operating plans. SP4 defines mission tasks, identifies needs for technology development, and documents DOE's current planning assumptions.

- RPP-RPT-41742, *River Protection Project Mission Analysis Report*, which establishes significant programmatic mission challenges (cost, schedule, and technical adequacy) and provides a basis for a structured framework to evaluate and understand potential solutions to the challenges.

Figure 1 shown below depicts the interconnecting planning relationships between the key documents in the RPP system. SP4, as the technical baseline, addresses the strategy to complete the RPP mission that includes tank waste retrievals, waste processing, and tank closures. SP4 identifies a baseline case scenario as well as "success criteria" that correlate to the proposed Consent Decree between DOE and Washington State to revise several mission milestones in the Hanford Site Federal Facility Agreement and Consent Order (Tri-Party Agreement or TPA). The SP4 baseline and Consent Decree dates that are relevant milestones for technology development are included in Table 2. This document uses the Consent Decree dates as mission targets for activities included in the decree and SP4 baseline dates for those activities not included in the decree.

Figure 1. Planning Relationships



DOE	Department of Energy	RPP	River Protection Project
ICD	Interface Control Document	TOC	Tank Operations Contractor
MAR	Mission Analysis Report	WTP	Waste Treatment and Immobilization Plant
PMB	Performance Measurement Baseline		

Table 2. Program Target Dates

Item #	Milestone Description	Consent Decree	SP4 Baseline Case
1	Complete C Farm Retrievals	09/2014	9/2014
2	Start Five Additional SST Retrievals	12/2017	12/2016
3	Complete Nine Additional SST Retrievals	09/2022	10/2017
4	WTP Hot Commissioning	N/A	2018
5	WTP Operations	N/A	2019
6	Close C Farm	06/2019	FY 2019
7	Deployment Of Second LAW Vitrification Facility	N/A	2021
8	Complete CH-TRU Waste Packaging	N/A	05/2022
9	Complete All SST Retrievals	12/2040	10/2041
10	Treat All Tank Waste	12/2047	01/2045
11	Close All SSTs	01/2043	FY 2048
12	Close All DSTs	09/2052	FY 2049

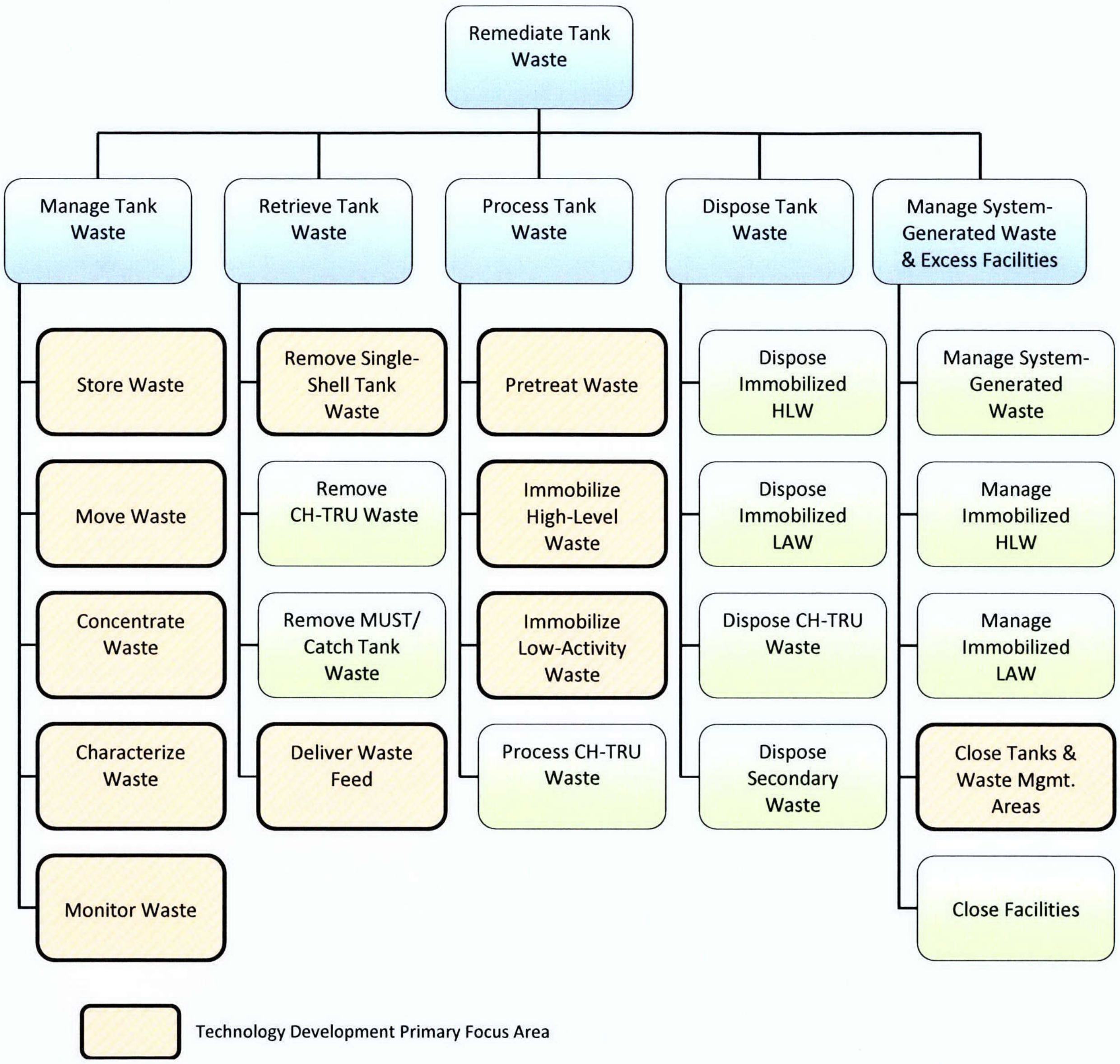
CH-TRU = contact-handled transuranic waste
DST = double shell tank
FY = fiscal year
LAW = low activity waste
N/A = not applicable
SST = single shell tank
WTP = Waste Treatment and Immobilization Plant
Success criteria/Consent Decree and baseline dates taken from RPP System Plan ORP-11242, *River Protection Project ORP-11242*, Rev. 4.

An essential part of SP4 development process includes modeling the RPP flow sheet using the Hanford Tank Waste Operations Simulator. A feedback loop exists between this modeling and technology development because the accuracy of modeling results depends on a thorough technical understanding of the behavior of processes and unit operations within the RPP flow sheet. Gaps in the knowledge base become a source for identifying technology development needs.

Inputs to the RPP-RPT-41742, *Mission Analysis Report,* include programmatic requirements from the DOE, environmental laws, SP4, "Interface Control Document for Waste Feed" (ICD 19), Tank Operations Contract (TOC), and TOC "Performance Measurement Baseline." DOE and other regulatory requirements are managed via the TOC and WTP contracts. Deficiencies or challenges identified in the Mission Analysis Report are targeted for technology development, trade studies, and/or flow sheet evaluations. The end result of this planning is the definition of project scopes necessary to complete the mission. The functions and requirements for each project flow down from the Mission Analysis Report and are further developed in project specific plans and specifications.

Figure 2 shows the RPP functional hierarchy (RPP-RPT-41742). Superimposed on Figure 2 are the functional areas (highlighted in orange with hatched pattern) that are the primary focus of this TDR.

Figure 2. River Protection Project Functional Hierarchy



The recently proposed judicial Consent Decree requires the DOE to decide on supplemental treatments no later than October 2014 (TPA milestone change package M-62-09-01). For purposes of these milestones, supplemental treatment may include, among other actions, enhancing WTP low activity waste (LAW) melter throughput, cold and hot testing of steam reforming, and evaluation and implementation of sodium management strategies.

3.0 TECHNOLOGY DEVELOPMENT PROGRAM OBJECTIVE

The Technology Development Program objective is to assist WRPS in successfully completing the RPP mission by identifying the currently known technology gaps that exist for the RPP mission and potential solutions. The program identifies efficient and effective activities, develops those activities with the participation of problem owners, solution providers, customers, and stakeholders as well as promotes accepted solutions. In addition to identifying the technology gaps and solutions, this TDR identifies the specific RPP mission milestones that drive these technology development activities. Implementation of the activities in this TDR can result in tasks being performed more quickly, with less funding, reduced environmental impacts, and/or increased safety.

Given the unique challenges that exist, only the development of new and innovative technologies will allow the successful completion of the RPP mission within the specified schedule. Certain issues such as LAW melter throughput and sodium loading in the waste must be addressed to meet the RPP mission schedule described in SP4. The WTP Support Technology and Development group exists to identify solutions to waste processing gaps and needs that exist in the current baseline and develop innovative solutions that will allow on-time mission completion. Also, given the magnitude of work required to treat Hanford's tank waste, any improvements that result in substantial cost and schedule reductions and/or risk mitigation should be undertaken. Specifically, if alternative treatments such as steam reforming can alleviate the need for a second LAW vitrification facility, significantly reducing overall processing time, cost, and risk then that technology should be pursued.

This TDR serves as a tool to help identify technical capabilities needed for the RPP mission, and assists with the development of plans to ensure that the knowledge and tools to achieve mission goals will be available when needed. To reduce the technical risk and uncertainty in the RPP mission, this document helps identify the technologies that need to be developed and when they need to be inserted into the evolving cleanup efforts. While the document identifies the current and near-term (1 to 10 years) technology development tasks being performed to address established technology gaps, it may not always provide the development tasks required for more distant future needs. Long-term (>10 years) technology development may rely on near-term development efforts to better define gaps.

The basic structure of this TDR will focus on identifying the broad scope of the technology functional areas that exist, technology gaps and opportunities within that functional area, and the technology solutions and activities being explored for each opportunity. It should be noted that in some cases, the solutions are broken down into discrete tasks, but in others they are grouped together for efficiency purposes. The following provide additional details.

Technology Functional Areas – The TOC functional areas are identified and defined in terms of their role in the tank farms mission with a high level description of the technology development challenges that exist at this time.

- **Technology Gap and Opportunity Identification** – The technology gaps and opportunities within each program area are identified in more detail. A technology gap may apply to an opportunity, as well as a technical risk or uncertainty.

- **Technology Solutions** – Potential solutions to the technology gaps and opportunities are described. These may include activities already being performed or planned for the future depending on the timing of the need. Also identified are the solution's current status, technology development priority, key decision points that the technology development work contributes to, and its potential insertion point.
- **Transformational Technology** – Within the Technology Solutions section of this report, several transformational technologies (i.e., innovative approaches potentially able to significantly reduce life-cycle cost, schedule, or technical risks) have been identified and are being investigated. Transformational technologies are discussed within this document as potential solutions to optimize the approach for completing the mission. These technologies, including some used in combination with others, may support greatly improved mission dates over those identified in Table 2.

Appendix A provides a matrix that summarizes the relationship between technology functional areas, their associated technology gaps, and technology solution development activities. The appendix also provides a cross link to the DOE 2008a, *"Engineering and Technology Roadmap – Reducing Technical Risk and Uncertainty in the EM Program,"* and DOE 2008b, *"Waste Processing Multi-Year Program Plan Fiscal Year 2008-2012,"* TFC-PLN-39, *"Risk Management Plan,"* and NAS 2009, *"Advice on the Department of Energy's Cleanup Technology Roadmap – Gaps and Bridges."*

Figure 3 shows the current plan and associated major schedule milestones to complete the Hanford tank farms mission. Figure 4 provides a more detailed look at the next fourteen years of the mission schedule. The implementation dates shown in Figure 4 are the result of mission needs analysis, and the decision dates are back calculated from the deployment dates. For example, the first melter replacement must be in 2024, and carries a six year procurement cycle. Therefore, selection decisions about the next generation melters must be made before 2018. Supporting technology development activities and scope, such as glass formulations, new melter technology studies, and testing are addressed in section 6.0.

Figure 4 illustrates that the next 14 years are critical to establishing the methods to accomplish treatment of the waste by 2047 and closure of all tanks by 2052. Technology development activities and significant improvements with respect to overall cost and schedule are required to complete the RPP mission. Additionally, process improvements focused on technology development tasks are needed to meet mission objectives.

Figure 3. River Protection Project Schedule of Major Activities (Baseline Plan)

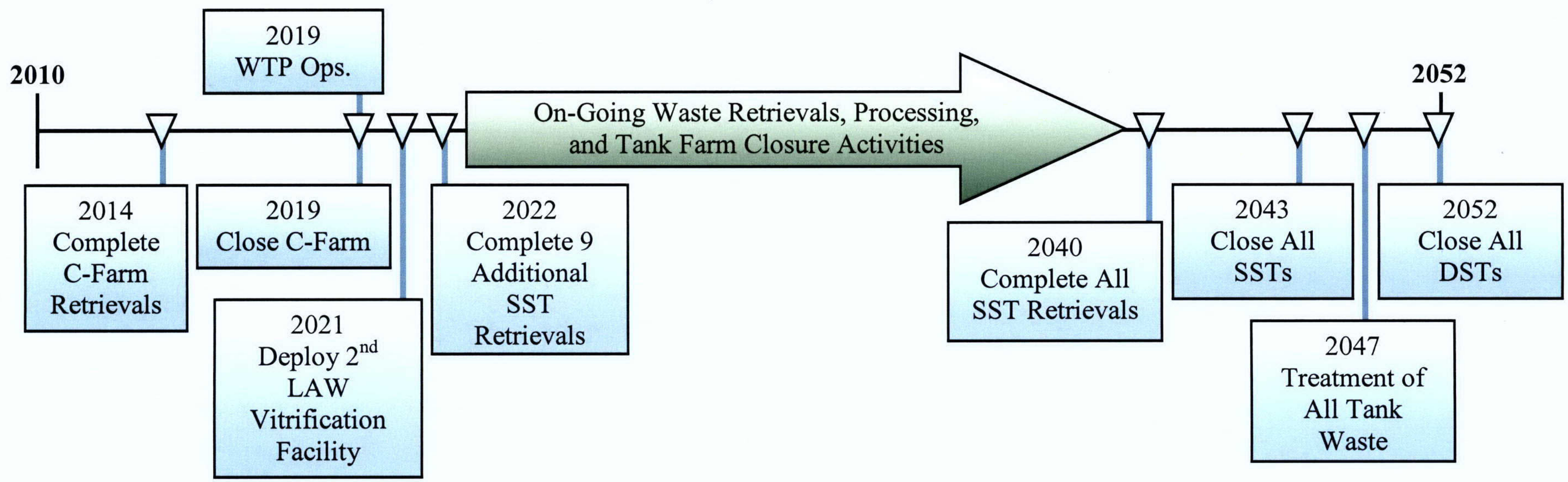
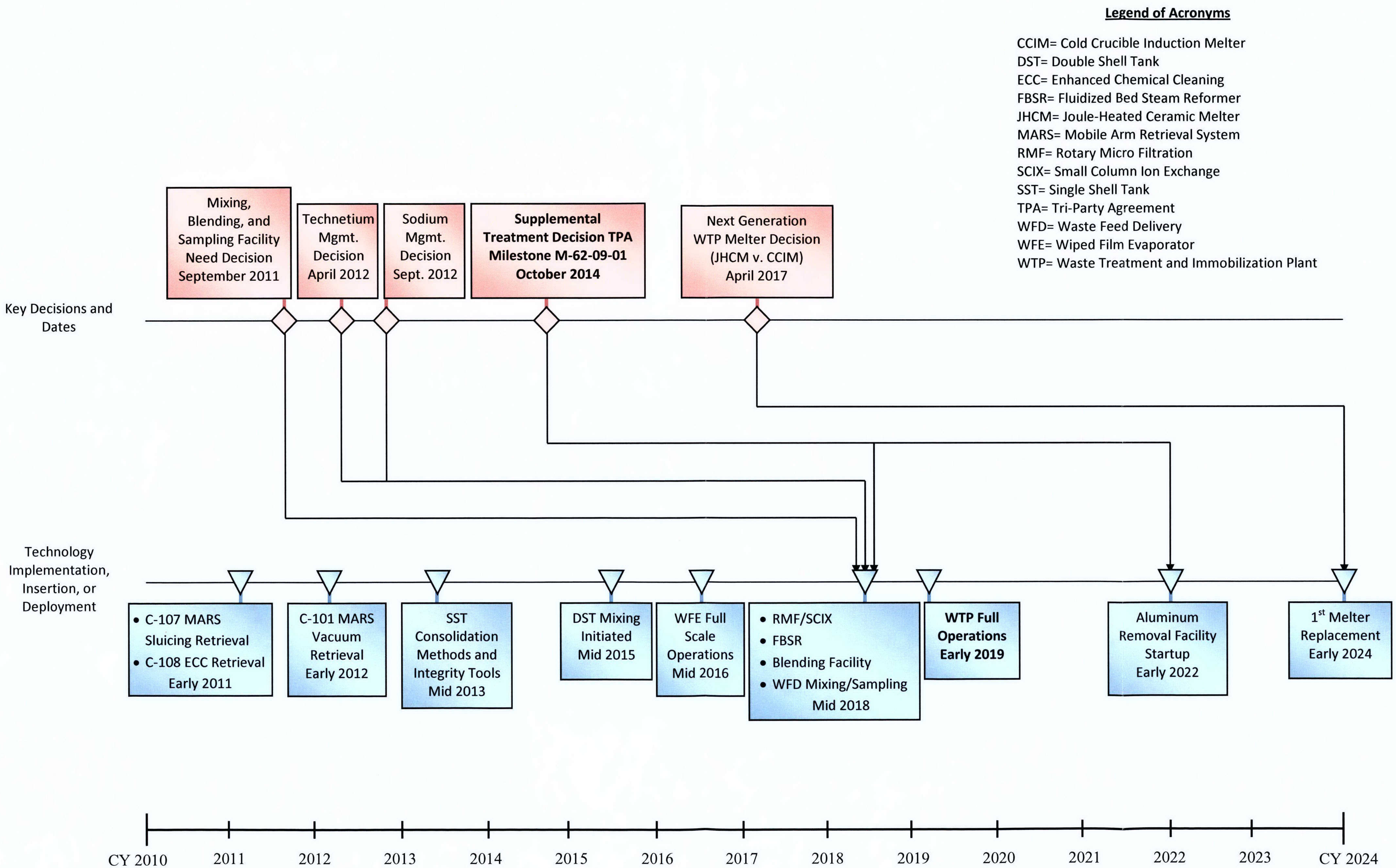


Figure 4. Fourteen Year Technology Development Schedule (Major Activities)



4.0 TECHNOLOGY DEVELOPMENT PROGRAM MANAGEMENT

The WTP Technology and Development organization is guided by this TDR to implement the selected technologies to cost effectively optimize program performance within applicable constraints imposed by the RPP mission. The focus is on near-term (1 to 10 years) issues. However, long-term (>10 years) issues are also being considered as planning efforts need to consider the entire RPP mission duration.

This TDR is a living document that will evolve with changes in needs and development of solutions. This roadmap will be updated on a recurring basis to incorporate the results of technology development activities and the latest customer priorities and budgetary guidance. Only those technologies currently identified and in development will be listed here. Technology projects that are completed or discontinued will be deleted from this report. An additional description and status of each technology identified for development can be found in RPP-RPT-46322, "*Technology Summary: Advancing Tank Waste Retrieval and Processing*."

The methods by which the technologies are to be developed are not specified in this roadmap. The TFC-PLN-90, "*Technology Development Plan*," provides the work processes for developing and deploying new technologies for WRPS. Technologies developed under the auspices of projects are managed in accordance with TFC-PLN-84, "*Tank Operations Contract Project Execution Plan.*"

5.0 PRIORITIZING TECHNOLOGY DEVELOPMENT

Given limitations of funding and the fact that some tasks require development of predecessor tasks prior to implementation, not all identified technology development tasks can be performed concurrently. Therefore, a method to prioritize the various technology development actions is needed to establish TOC guidance for funding and program execution decisions. The methodology to prioritize the technology development activities in this TDR is described below.

5.1 NEAR-TERM TECHNOLOGY DEVELOPMENT SCHEDULING

Scheduling of near-term technology development activities is driven by the need to complete the technology development maturation and implementation on or before the date at which it is required to support the mission schedule milestones and/or the program objectives listed in Section 6.0.

However, the timing of initial actions to develop a technology solution must consider the various lags between the technology maturation process and the mission objectives. Factors that must be considered include design, procurement, construction, and operation actions that are required to implement a technology solution that successfully achieves a mission objective, as well as the timing and unique criteria for each technology.

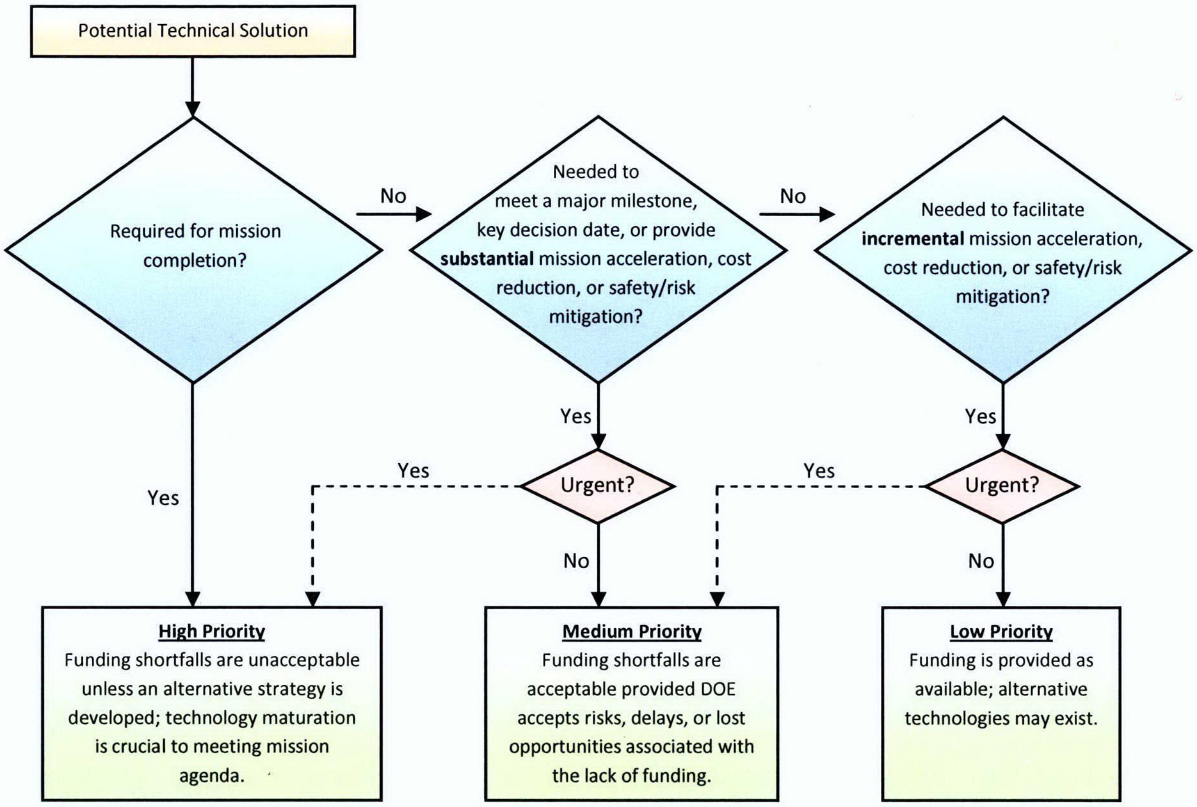
5.2 PRIORITIZATION METHODOLOGY

Several methods of setting priorities could be applied to technology development actions. Unlike comparing alternatives that have been identified to address the same need (e.g., multiple technologies identified for tank heel retrieval), a system is required to compare the relative priorities of multiple technologies that address different needs (e.g. waste storage, waste retrieval, waste treatment, etc.) is required. Any ranking/comparison system that is chosen requires methods to determine the urgency of the need and the potential benefit of the proposed technology solution. The urgency of a technology need is related to timing, while the benefit of the solution is related to the magnitude of its contribution to the overall mission success, if implemented.

In determining the benefit of a technology solution, it is important to ascertain whether it addresses a "need-to-have" imperative or a "nice-to-have" addition. In other words, does it provide a solution that does not yet exist, but is required to allow completion of the mission? Or does it offer incremental improvement resulting in greater efficiency, cost avoidance, or other benefit?

Figure 5 illustrates the logic for prioritizing technology development actions. This logic assumes that baseline scheduling for technology development actions have appropriately captured the required insertion dates and maturation process. Therefore, the primary factor that would prevent technology development in accordance with the baseline schedule is a shortfall in available funding.

Figure 5. Mission Driven Technology Development Prioritization Logic



High Priority Technologies: These technologies are mission critical and need to be fully funded immediately to avoid missed milestones, decision dates, or lost opportunities for substantial mission execution gains.

Medium Priority Technologies: These technologies are not mission critical but would help the TOC meet major milestones or decision dates. Additionally, these technologies could provide *substantial* mission acceleration, cost reduction, or safety and/or risk mitigation. If the urgent development and subsequent implementation of any of these technologies provide significant benefits, then the priority level could be escalated to High. Funding shortfalls for these technologies could be mitigated or worked around, but the DOE would then have to accept any lost opportunities associated with the funding gap.

Low Priority Technologies: These technologies provide *incremental* mission acceleration, cost reduction, or safety and/or risk mitigation. If the benefits can be maximized by urgent development of any of these technologies, then their priority level could be escalated to Medium. Funding should be allocated to these technologies as available.

In addition to the evaluation criteria identified above, DOE's Office of River Protection (ORP) implements performance-based incentives (PBIs) to focus TOC efforts on selected high priority/high visibility work tasks. However, the PBIs are developed on an annual basis and are used to accelerate or focus efforts on near-term tasks that have already been planned, whereas the TDR is focused on future efforts. Therefore, the PBIs are not included in this TDR.

6.0 TECHNOLOGY FUNCTIONAL AREAS

The TOC's technology development functional areas are identified as Safe Waste Storage, Waste Retrieval, Tank Closure, and Waste Pretreatment and Stabilization. Tank Farms Operation also may require technology development. These functional areas may each have multiple technology gaps, risks, opportunities, and solutions identified within them. Many of the risks and opportunities identified in the Risk Management Plan correlate to these functional areas. However, some risks and opportunities identified in the Risk Management Plan do not correlate to technology development in a TOC functional area (e.g., work stoppages, skill mix, and labor shortages). A cross-walk from the TDR to the Risk Management Plan (RMP) is included in Table A-1, "Technology Summary Development Matrix."

Figure 6 shows the simplified process flow diagram for the SP4 Baseline Case. This depiction is consistent with the current Performance Measurement Baseline. WRPS is working with DOE Headquarters and the ORP to develop an accelerated treatment plan for the Hanford tank waste. A pre-decisional flow diagram for the accelerated treatment plan is shown in Figure 7. This TDR will discuss current technology gaps as related to plans for acceleration and/or successful completion of the mission schedule. Each functional area will be described at a high level, and then discussed with respect to gaps/opportunities that have been identified. For each area, technology solutions including transformational technologies will be listed.

Figure 6. Summary River Protection Project Baseline Process Flow Diagram.

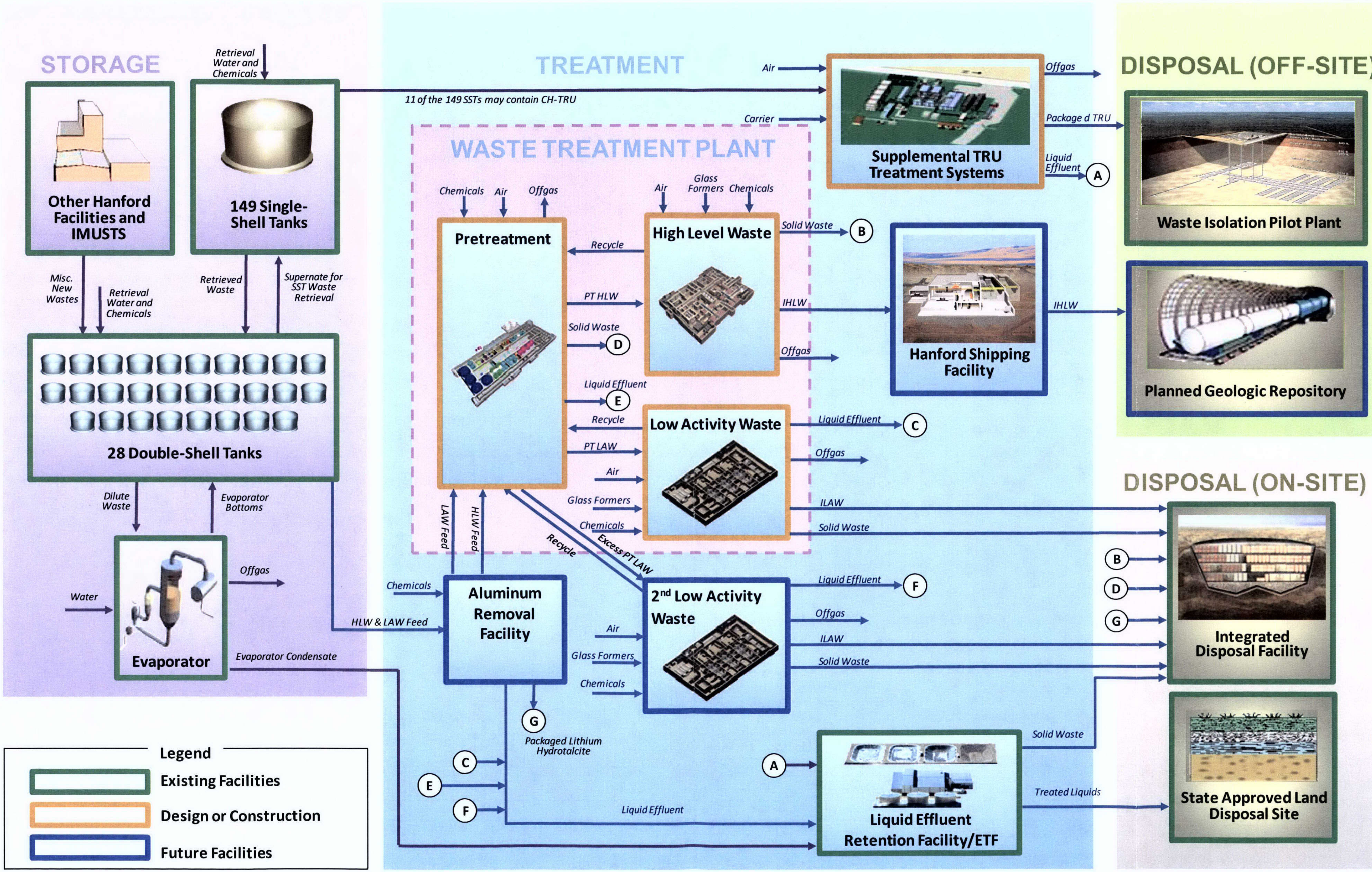
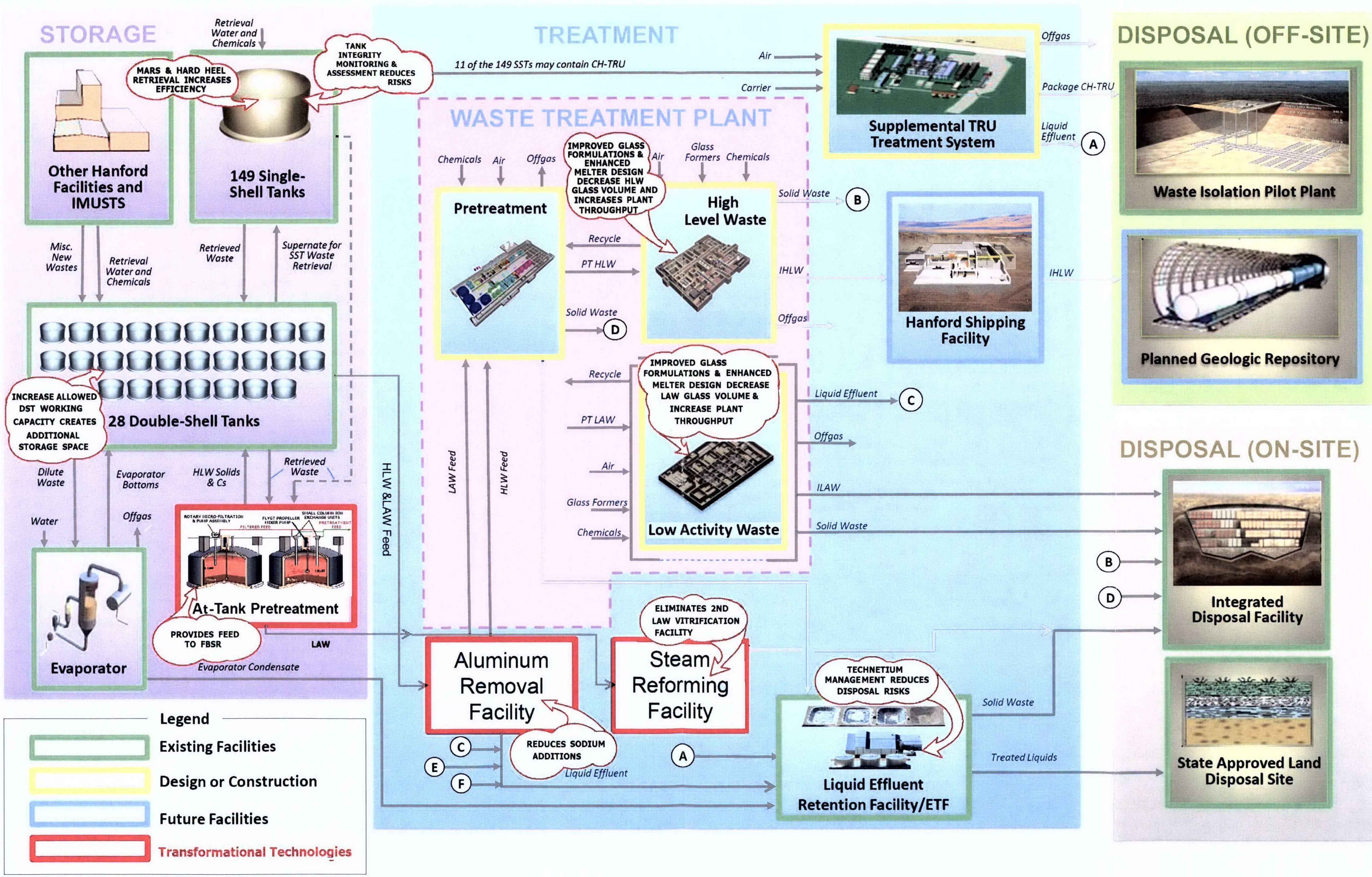


Figure 7. Summary River Protection Project Accelerated Process Flow Diagram.



6.1 SAFE WASTE STORAGE

The challenge of safely storing waste in the tank farms prior to its delivery to the WTP or alternate treatment paths and subsequent tank closure is relevant to both SSTs and DSTs. The tanks will have exceeded their original design life prior to closure. Therefore, verification of their structural and leak integrity is crucial.

The Hanford DST system also has very little available storage space for SST retrievals. SP4 predicts that by 2018 there will not be enough DST storage space to continue SST retrievals until the WTP is operating at full capacity and a substantial quantity of DST waste has been transferred to WTP for processing.

6.1.1 Safe Waste Storage Technology Gaps and Opportunities

Tank monitoring and integrity assessment capabilities need to be improved to continue safely storing waste in aging tanks. These capabilities may include tank structural modeling, tank inspection tools and methods (including inspection of concrete, internal rebar, and steel liners and bottoms), and better understanding of corrosion mechanisms.

In addition, a better understanding of waste chemistry and physical properties is needed for RPP flow sheet modeling. New studies and tools may include development of in-situ methods for determining a waste slurry's particle size distribution and rheological behavior. Fundamental research is also required to develop correlations for estimating supernate viscosity as a function of composition.

6.1.2 Safe Waste Storage Technology Solutions

6.1.2.1 Tank Integrity Tools and Methods – Adaptation of existing technologies such as ultrasound probes for deployment in the tank environment is required to more accurately assess a tank's integrity. Incomplete understanding of tank structural vulnerability and chemical corrosion mechanisms make it difficult to maintain a tank's integrity and maximize its use. New, detailed structural modeling as well as continued development of in-tank corrosion probes, chemical sensors, and non-destructive examination methods would assist in maximizing the use of existing tanks toward continued use including waste consolidation in SSTs to alleviate the DST space shortfall.

Status – The TOC has established a tank integrity program for the DSTs and has, with the assistance of an expert panel, started development of an SST integrity program in fiscal year (FY) 2009.

Technology Development Priority – Medium

Insertion Point – SST/DST Integrity Programs- As soon as practical to support SST and DST operation and extended service life needs.

– SST Consolidation Methods- 2013

6.1.2.2 Increasing Tank Working Capacity – The potential for retention of flammable gases limits the working capacity of some DSTs below that based on structural dimensions. To mitigate the potential to exceed the lower flammability limits for hydrogen, assumptions about the waste properties have resulted in conservative models that preclude optimizing DST space. The development of new technologies to measure actual sludge shear strength and estimate gas retention could allow the DST safety basis to be revised to increase allowed working volume.

Status – A cone penetrometer measurement tool was tested in FY 2009. This tool should allow data to be collected that could quantify the degree of conservatism in buoyant displacement gas release event models.

Technology Development Priority – High

Insertion Point – 2012 planned deployment in tank AN-106 to avoid or alleviate DST storage space shortfall

6.1.2.3 Wiped Film Evaporator (transformational technology) – Applying Wiped Film Evaporator (WFE) technology to Hanford tank waste would provide a transportable system to evaporate SST waste, DST waste, secondary waste, and TRU mixed waste. This system would reduce the volume of waste requiring storage and eliminate the current total dependence on the 242-A Evaporator.

Status – The wiped film evaporator development has been projectized to mature the technology so that it can be deployed at Hanford. The project schedule indicates that the wiped film evaporator will enter the procurement cycle beginning mid-FY 2010.

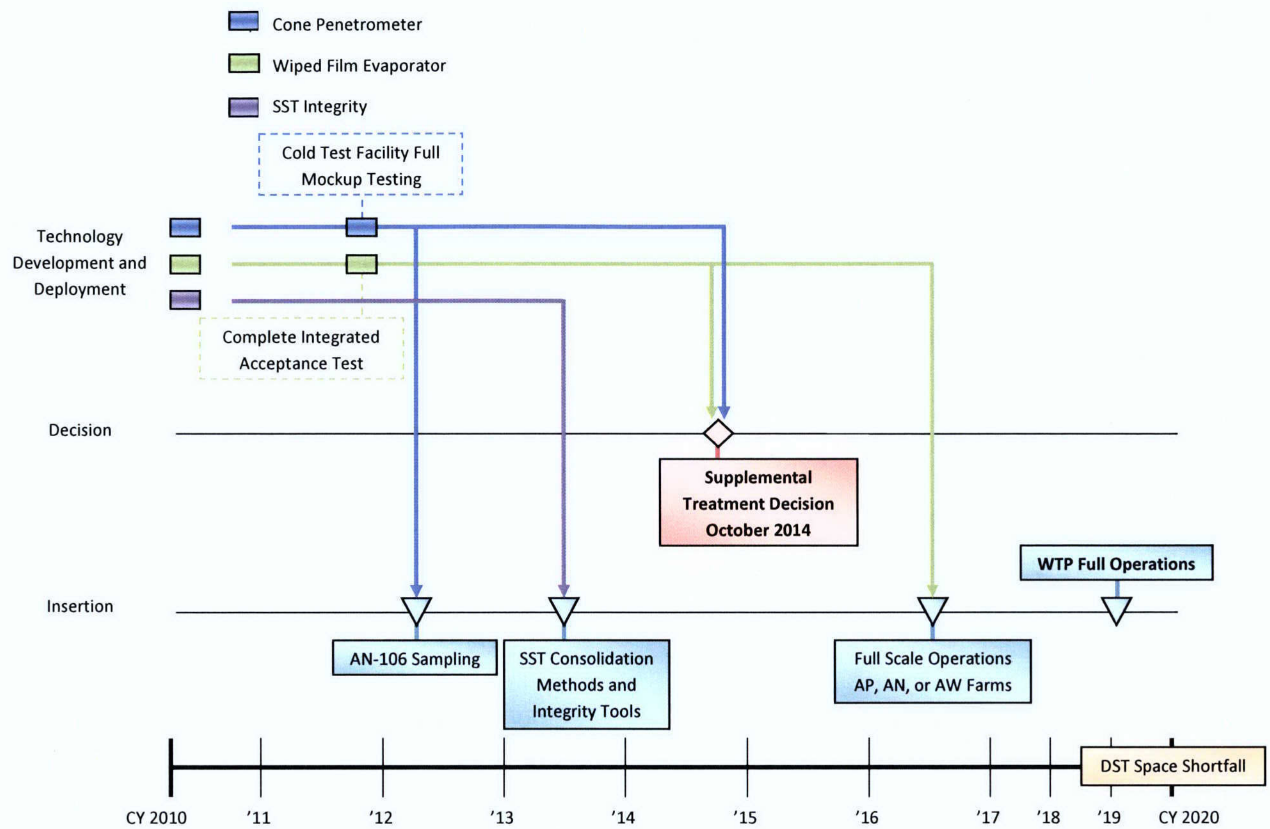
Technology Development Priority – Medium

Decision Point – 2014 Supplemental treatment decision (M-62-09-01)

Insertion Point – 2016 full scale operation to avoid or alleviate DST storage space shortfall

Technology Development and Deployment (TDD) Timeline – Figure 8 depicts the known major TDD activities, decisions, and insertion points for the WFE, cone penetrometer, and SST Integrity project activity. After successful completion of the integrated acceptance test, the WFE will be deployed to AP, AN, or AW Farm.

Figure 8. Safe Waste Storage Technology Solutions – Major Implementation Activities



6.2 WASTE RETRIEVAL

Between 1943 and 1964, 149 SSTs were built to store radioactive waste. Each SST is an underground, reinforced concrete structure with a carbon steel liner covering the concrete base and walls. The 100-series tanks are 75-ft diameter tanks that range in capacity from 530,000 gallons to 1,000,000 gallons. The smaller, 200-series tanks are 20-ft diameter 55,000 gallon tanks. The tank waste forms include the bulk waste and a hard heel. These tanks contain various pieces of installed equipment including pumps, thermocouple trees, saltwell screens, dry wells, and air-lift circulators.

The TPA includes commitments to complete specific waste retrieval activities on or before specified dates, as well as commitments to remove 99% of the tank waste by volume. This volume commitment equates to $\leq 360\ ft^3$ (2,693 gal) for 100-series tanks and $\leq 30\ ft^3$ (224 gal) for 200-series tanks. Table 3 provides the waste volumes in SSTs that will need to be retrieved, treated, and immobilized.

Table 3. Approximate Single Shell Tank Farm Waste Volumes.

Tank Type	200 East Area	200 West Area	Total
Single shell tanks	10.5 Mgal	19.2 Mgal	29.7 Mgal

Values taken from DOE 2009, ORP-11242, 2009, *River Protection Project System Plan ORP-11242*, Rev. 4, U. S. Department of Energy – Office of River Protection, Richland, Washington.

The TOC must develop technologies to improve waste retrieval processes to meet or exceed the schedule for the major activities listed in Table 4, which were extracted from SP4. As depicted in Figure 9, retrieval has been completed on six SSTs, and one retrieval is still being reviewed by the Washington State Department of Ecology.

Table 4. Tank Retrieval Goals.

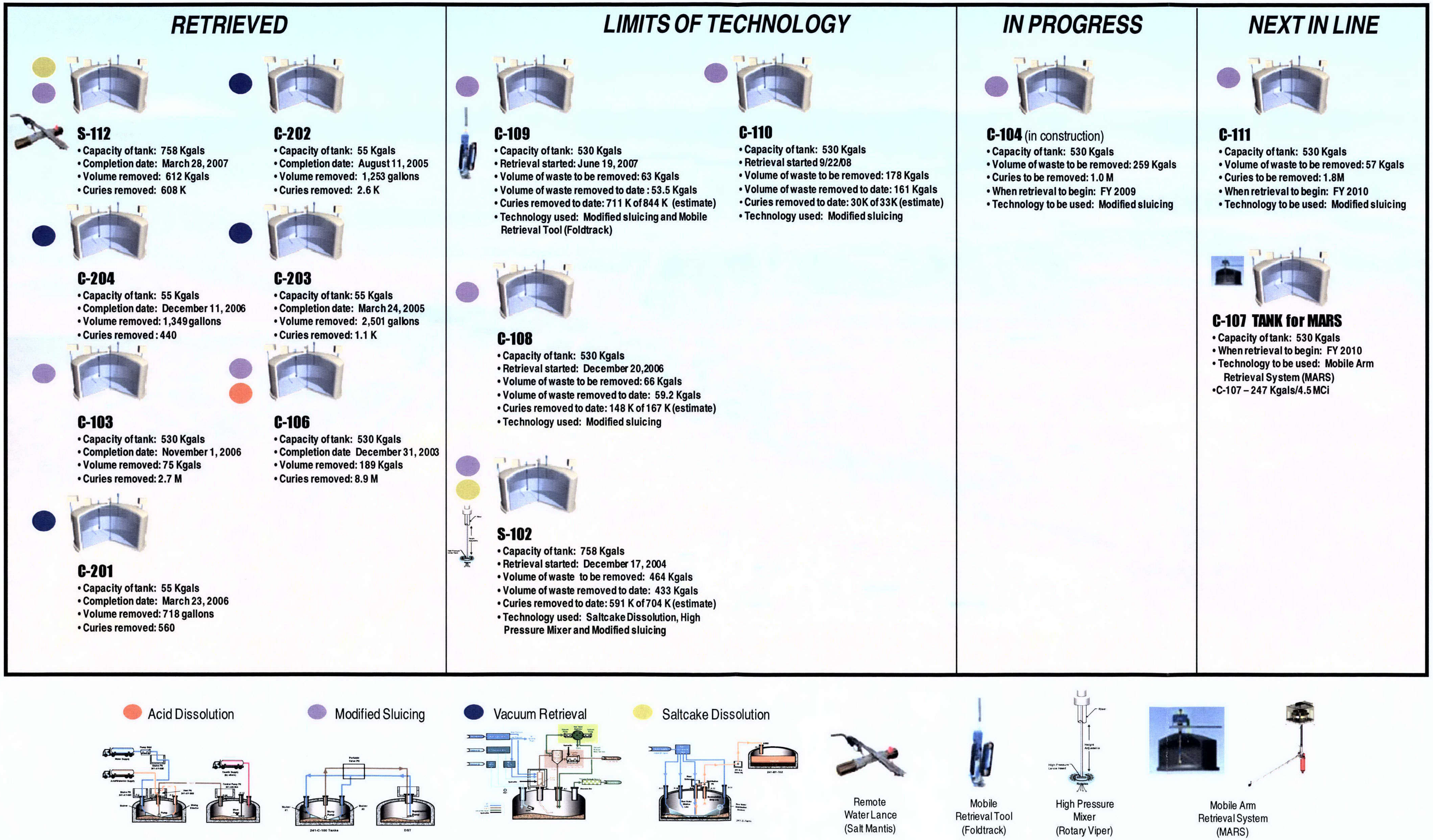
Metric	Mission Target
Complete C Farm retrievals	9/2014
Start 5 additional SST retrievals	12/2017
Complete CH-TRU waste packaging	5/2022
Complete 9 Additional retrievals	9/2022
Complete all SST retrievals	12/2040

Values taken from DOE 2009, ORP-11242, 2009, *River Protection Project System Plan ORP-11242*, Rev. 4, U. S. Department of Energy – Office of River Protection, Richland, Washington.

The RPP-PLAN-40145, *Single Shell Tank Waste Retrieval Plan*, currently identifies the following methods for bulk waste retrieval (i.e., retrieval of waste down to any difficult-to-remove heel):

- Modified sluicing with DST supernate or water
- Vacuum retrieval
- An alternative process that would be either a restricted form of modified sluicing that maintains free liquid at a minimum observable quantity, a robotic arm, or an alternative retrieval process not yet developed.

Figure 9. Hanford Tank Cleanup Status



6.2.1 Waste Retrieval Technology Gaps (WP-1) and Opportunities

More efficient and effective means of retrieving the Hanford SSTs are required. The retrieval methods and tools must minimize the quantity of waste generated given the limited available DST storage space and impacts to downstream processes (e.g., WTP). Modified sluicing has been shown to be effective in retrieving approximately 90% of the volume of waste in the tanks. The remaining 10% of the waste (referred to as the hard heel) has proven difficult for the sluicing system to retrieve. Therefore, supplemental tools and methods need to be developed for enhanced retrieval capabilities. These methods may include mechanical and/or chemical dissolution processes. A hard heel waste retrieval technology review and roadmap, RPP-RPT-44139, *Hard Heel Waste Retrieval Technology Review and Roadmap*, Rev. 0, was issued early in FY 2010 that describes retrieval technology development at a more detailed level. The phased deployment of enhanced retrieval methods will continue as they are developed and as needed to support the evolving tank retrieval goals.

Retrieval of assumed leaking tanks must also be included in retrieval systems development. Retrieval of the first 100-series assumed leaking tank, C-101, is planned to begin in 2012.

In addition, there are several "special case" tanks identified in the RPP-PLAN-40145 that require further evaluation to determine the preferred retrieval method. Due to the conditions of the tank and/or waste, these tanks pose more complex retrieval challenges that may require more specialized retrieval methods to be developed and implemented. The first special case tank (AX-104) retrieval is planned for 2018. This tank has been identified as a candidate for chemical dissolution.

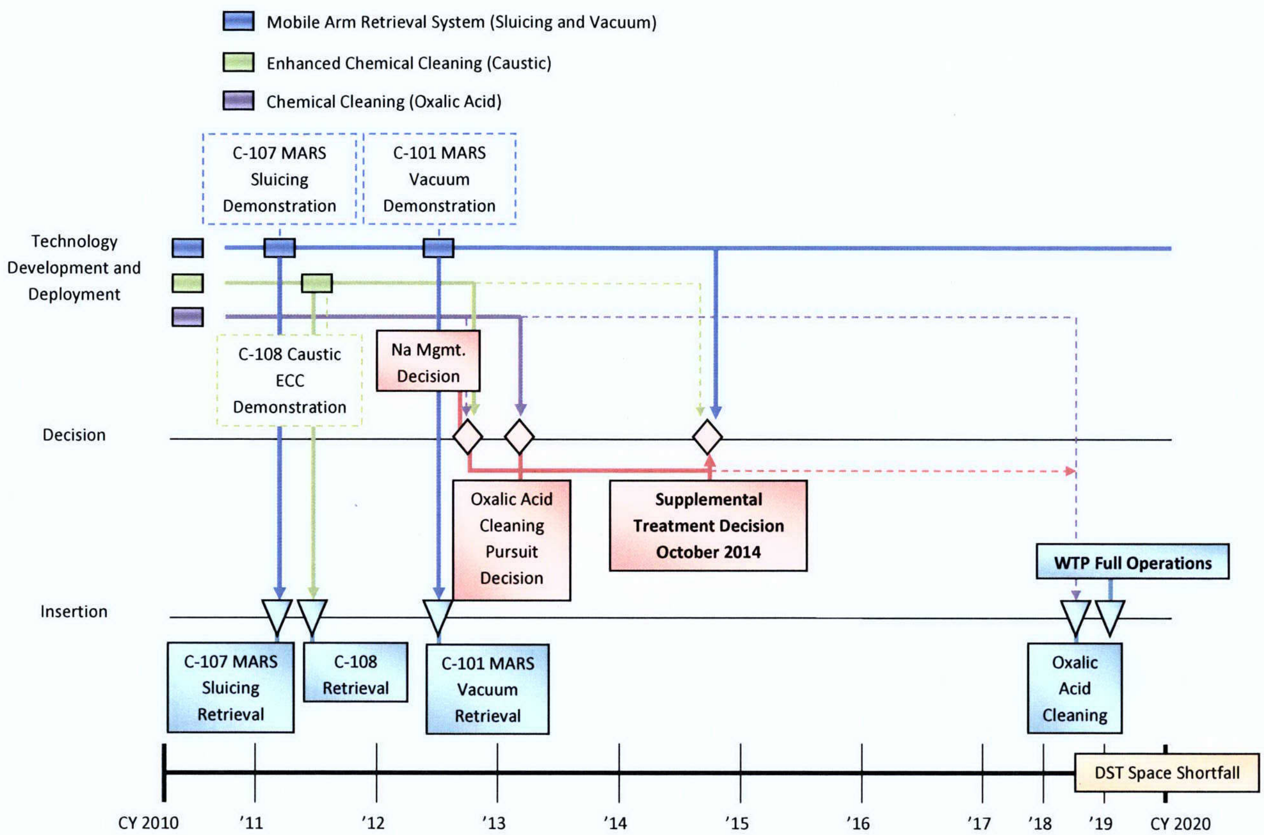
6.2.2 Waste Retrieval Technology Solutions

6.2.2.1 Mobile Arm Retrieval System (MARS) (transformational technology) – The MARS is currently being developed to retrieve bulk and heel waste from both sound SSTs and those assumed to be leaking. The MARS is envisioned as a device that allows different types of retrieval tools to be deployed in all areas of the tank. There are two versions of the MARS under development: one for a sound tank that uses a sluicing head to mobilize the waste to the centrally located transfer pump, and another for an assumed leaking tank that utilizes a vacuum system with localized scarifying to mobilize and retrieve the waste.

> **Status** – Retrieval development has been projectized. A prototypic sluicing MARS is undergoing testing at the Cold Test Facility.
>
> **Technology Development Priority – High**
>
> **Insertion Points** – 2011 Sluicing retrieval in sound tank,
> –2012 Vacuum retrieval in assumed leaking tank

TDD Timeline – Figure 10 depicts major TDD activities, decisions, and insertion points for SST retrieval. Demonstration of the MARS in the sluicing mode is planned for C-107 retrieval, and the MARS in the vacuum mode is planned for C-101. Figure 10 also depicts major activities related to caustic and acidic tank cleaning as they relate to retrievals (see Section 6.2.2.2).

Figure 10. Single Shell Tank Retrieval – Major Implementation Activities



6.2.2.2 Chemical Cleaning – Chemical treatments will be considered to assist with tank retrievals because sluicing hard heel materials has limits and potential in-tank obstructions can limit the range and effectiveness of retrieval equipment (including the MARS). One type of chemical treatment described as Enhanced Chemical Cleaning that is being pursued involves high molarity caustic addition to metathesize sodium aluminate compounds (primarily gibbsite) followed by water addition to dissolve the waste heel solids and facilitate waste retrieval. This approach would apply to waste heels that consist largely of sodium aluminate compounds and would facilitate the volume-based retrieval goals set forth by the TPA.

A second chemical treatment being investigated to dissolve the waste heel is oxalic acid cleaning. Oxalic acid was effective on the Savannah River Site (SRS) tank heels and was used as part of Hanford's tank C-106 retrieval. However, oxalic acid needs to be neutralized with caustic after use, and the neutralized oxalate exhibits a low solubility in high sodium solutions. The caustic addition also increases the WTP LAW glass volume. In addition, the potential buildup of oxalate in the WTP pretreatment facility has been identified as an issue. Therefore, a means to destroy oxalic acid after it has performed its intended function needs to be investigated.

Status – An Enhanced Chemical Cleaning demonstration in the first quarter of FY 2011 is planned as part of C-108 Retrieval. An oxalic acid cleaning demonstration is planned for FY 2018 as part of AX-102 Retrieval.

Technology Development Priority – High

Decision Points – 2012 Sodium management decision,

Insertion Points – 2011 Caustic cleaning demonstration,
– 2018 Oxalic acid cleaning demonstration

6.2.2.3 Waste Rheology – Transport of retrieved waste with minimal risk of line plugging is dependent on its rheological behavior. Waste transfer studies and tests are needed to better define the point where key constituents (e.g., phosphate concentration) impart unacceptable risk. This technology is also applicable to Waste Feed Delivery functional area in Section 6.3.2.5.5.

Status – Planned FY 2010 and 2011 testing is being directed and funded by EM.

Technology Development Priority – Low

Decision/Insertion Point – As soon as practical to support SST retrievals and waste feed delivery

6.2.2.4 In-Tank Elutriation – An alternate approach to basing retrieval goals on volume is to base them on risk reduction. A risk reduction approach to tank retrievals would focus on the environmental impact of the residual material left in a tank, rather than on volume.

If regulatory approval for risk-based retrieval were received, it would create a new avenue for technology development. Inadvertent elutriation during S-112 retrieval resulted in a heel composed almost entirely of large (~100 μm) particles of pure gibbsite with greatly reduced radionuclide concentrations. Presumably, even better radionuclide separation from the gibbsite heel could be attained if this physical separation process were done intentionally with an in-tank elutriation column.

Status – Preliminary planning underway.

Technology Development Priority – Low

Decision/Insertion Point – As soon as practical to support SST retrievals

6.3 WASTE PRETREATMENT AND STABILIZATION

Hanford's WTP is scheduled to initiate hot commissioning in 2018 and begin operations in 2019. The TOC must be able to supply the appropriate feed to support the startup and continued operation of the WTP, as well as receive secondary wastes from the WTP during operation. The challenges include mixing, blending, and sampling tank waste to meet the WTP acceptance criteria identified in the Interface Control Document for Waste Feed (ICD-19), and possibly implementing supplemental tank waste pretreatment and secondary waste treatment methods. The WTP will pretreat waste transferred from the tank farms to separate it into a high level waste (HLW) fraction and a LAW fraction, with each fraction being processed separately into glass.

The WTP (under construction at this time) will immobilize all of the HLW and approximately one third of the LAW. Supplemental treatment capacity has been planned to allow LAW treatment to finish concurrently with HLW treatment. At this time, a second LAW vitrification facility is planned to treat the remaining two-thirds of the LAW. Major decisions must be made regarding the use of supplemental treatment, related technologies, and the relationship between the TOC and WTP. Although SP4 assumes a second LAW facility will be implemented, no final decisions regarding supplemental technology can be made until the Record of Decision is issued by DOE for the DOE/EIS-0391, *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

The TOC must develop technologies to support the WTP that meet or exceed objectives identified in Table 5.

Table 5. Waste Treatment and Immobilization Plant Objectives.

Metric	Mission Target
Treat all tank waste	12/2047
LAW glass mass (MTG)	448,800
LAW glass packages	75,810
HLW glass mass (MTG)	42,899
HLW glass canisters	14,111
CH-TRU waste drums	7,491
Waste Sodium reporting to LAW glass	52,200 MT
LAW glass sodium oxide loading	15.7%
HLW glass waste oxide loading	31.1%

CH-TRU = contact-handled transuranic waste
LAW = low activity waste
HLW = high level waste
Values taken from DOE 2009, ORP-11242, 2009, *River Protection Project System Plan ORP-11242*, Rev. 4, U. S. Department of Energy – Office of River Protection, Richland, Washington.

6.3.1 Waste Pretreatment and Stabilization Technology Gaps (WP-2, WP-3, WP-4, and WP-5) and Opportunities

In addition to the technology development required within the tank farms to provide feed to the WTP, the TOC must try to optimize the WTP operations to reduce the schedule and costs of waste treatment and disposal. These optimization strategies will include improved methods to separate inert materials and LAW from HLW tank waste, improved glass formulations to increase waste loading, and improved melter technology to allow higher throughput. Given the considerable amount of Hanford waste that needs to be treated, even incremental improvements in any of these areas could result in substantial cost and schedule savings.

6.3.2 Waste Pretreatment and Stabilization Technology Solutions

6.3.2.1 Waste Feed Delivery Mixing and Certification Sampling – Waste retrieved from SSTs will be transferred and consolidated in DSTs, prior to transfer to WTP. The ability to adequately mix the waste in the DSTs to meet the WTP acceptance requirements needs to be developed and demonstrated. The technology solution will include computer modeling and testing of tank mixing.

Sampling of DSTs is required to support sludge management and develop a WTP feed strategy, to ensure that the appropriate (and preferably optimal) feed is consistently provided to the WTP. A waste characterization sample loop must also be developed to ensure that the feed meets WTP needs.

Status – Scale mixing testing is in progress in FY 2010 with a draft report to be issued by the end of the fiscal year. Scaled sampling and batch transfer testing is planned for FY 2011.

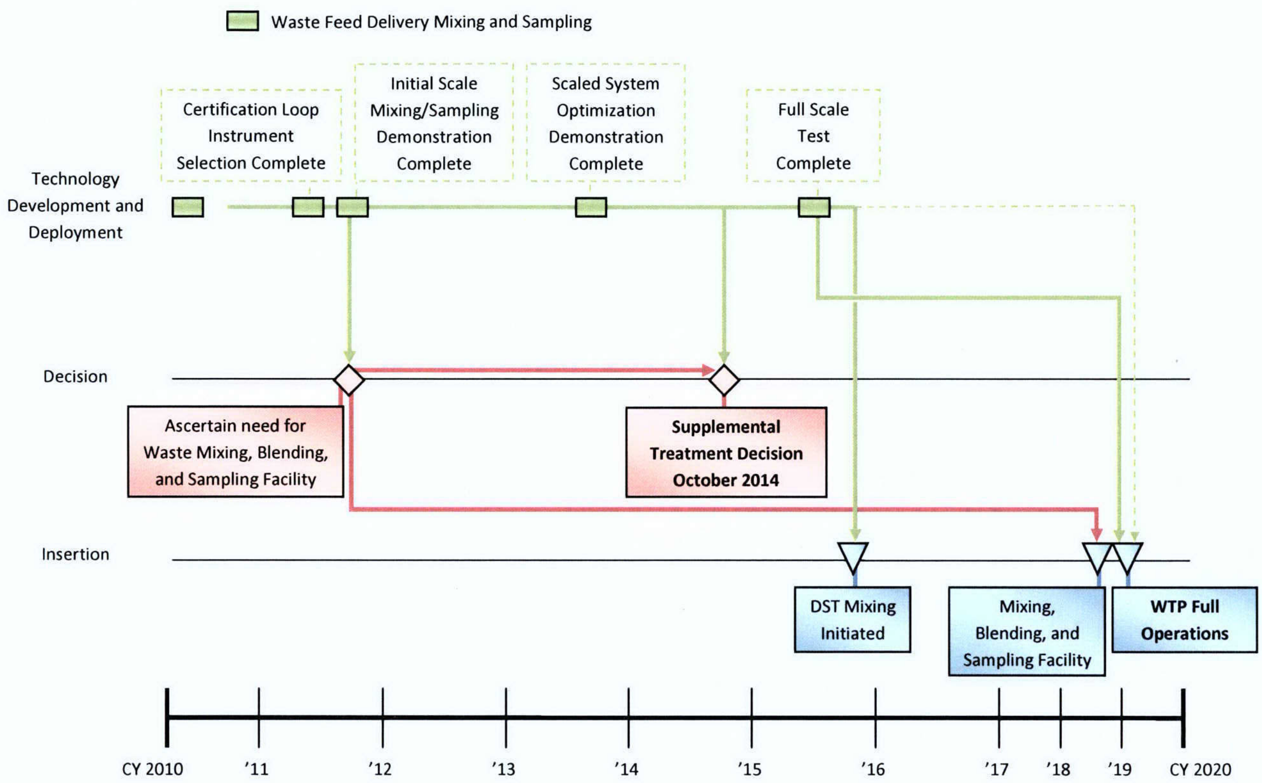
Technology Development Priority – High

Decision Points – 2011 Waste mixing, blending (see Section 6.3.2.5.1), and certification sampling facility

Insertion Points – 2018 Potential mixing and blending facility commissioning
– 2019 WTP Operations support

TDD Timeline – Figure 11 depicts major TDD activities, decisions, and insertion points for the waste feed delivery mixing and certification sampling. If initial testing indicates that installation of two mixer pumps in the DSTs will not provide sufficient mixing for waste feed delivery, waste feed delivery mixing and certification sampling functions may be included in the Waste Receipt Facility Project scope.

Figure 11. Waste Feed Delivery Mixing and Certification Sampling – Major Implementation Activities



6.3.2.2 Glass and Cast Stone Testing for IDF – The LAW glass and possibly cast stone waste forms will be disposed onsite at the Integrated Disposal Facility (IDF). Testing of these waste forms for acceptability when disposed of in the IDF is required and described by the IDF Waste Acceptance Criteria (WAC).

Status – Glass and cast stone IDF WAC compliance testing was performed in FY 2009 and further testing may be conducted as necessitated by new glass or cast stone formulations.

Technology Development Priority – Low

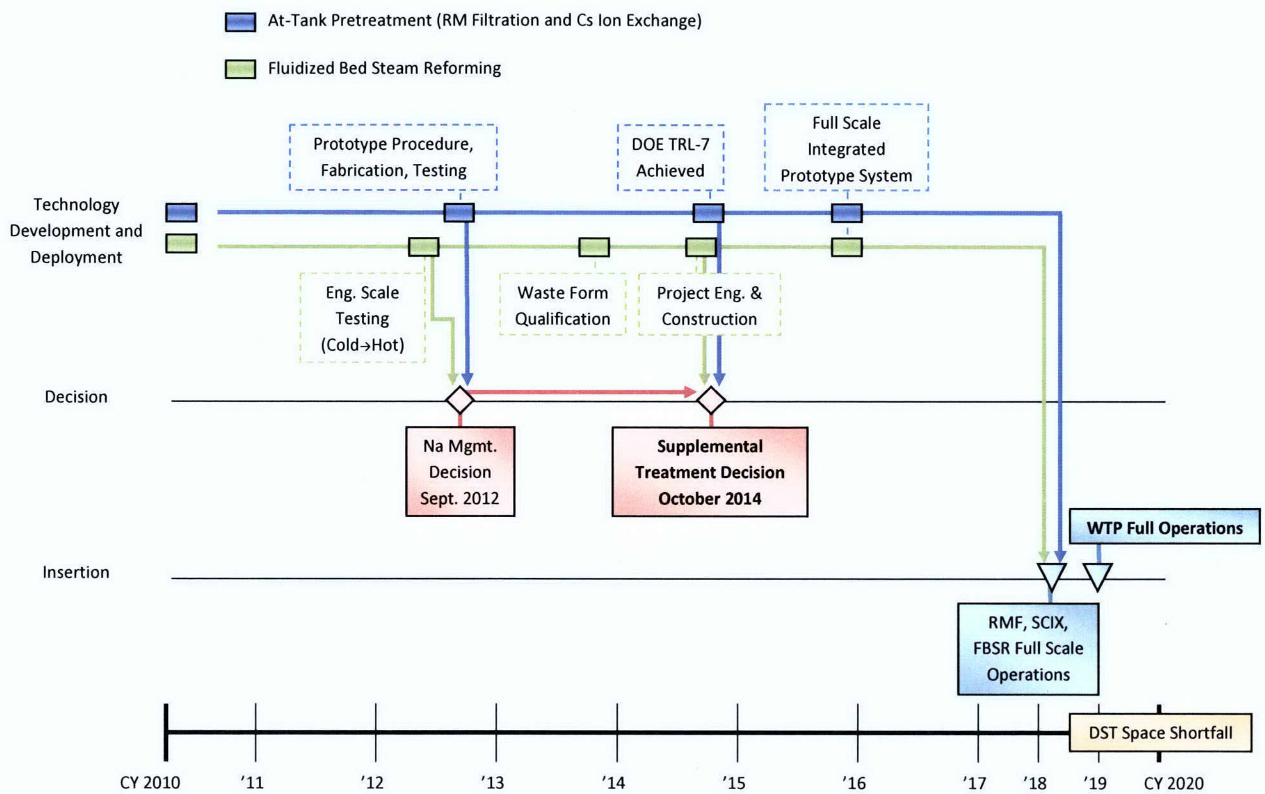
6.3.2.3 At-Tank Integrated Pretreatment System – The mission target of treating all tank waste by December 2047 cannot be achieved without additional tank waste treatment capacity, given the throughput limits of WTP pretreatment and LAW vitrification. An option to provide the required supplemental production is to integrate at-tank filtration and small column ion exchange (SCIX) with steam reforming. For the steam reforming system to operate without the support of WTP pretreatment it must be furnished with its own filtration and SCIX systems. These systems are required to separate tank waste into a HLW fraction and a LAW fraction. The SCIX also allows the steam reforming process to be contact-maintained. See Section 6.3.2.6.1 for additional information on the steam reforming activity.

Although the individual systems (steam reforming, rotary microfilter, and SCIX) will be developed individually, the integrated system must also be demonstrated. This demonstration will identify issues that result from coupling individual systems together, and lead to development of corrective actions.

The primary purpose for field deployment of an at-tank integrated system is to provide a supplemental treatment capability, potentially eliminating the need for the second LAW facility. However, if field deployment were sufficiently accelerated it could also alleviate some of the shortage in DST space. (Note that the term "at-tank" is used in this document to refer to a system that is installed in any combination of in, on, or near the waste tank.)

TDD Timeline – Figure 12 depicts major TDD activities, decisions, and insertion points for the at-tank integrated system (filtration, ion exchange, and steam reforming). This system is related to aluminum and sodium management only insofar as it may be more cost effective to increase LAW immobilization capacity with an at-tank integrated system than to deploy technology that generates a recyclable caustic stream.

Figure 12. At-Tank Integrated System – Major Implementation Activities



6.3.2.3.1 At-Tank Filtration (transformational technology) – Limited WTP pretreatment capacity can lengthen the mission. The at-tank filtration process could supplement the ultra-filtration system, and thus alleviate shortfalls in feed production to the HLW and LAW vitrification facilities. Using an at-tank process to produce filtered supernate (using rotary microfilters) to feed the Pretreatment Facility would allow the supernate to bypass that facility's ultra-filtration system and be routed directly to the cesium ion exchange process. This process would allow the ultra-filtration system operation to focus on providing feed to the HLW vitrification facility. At-tank filtration is also required to support the at-tank integrated system previously discussed in this TDR.

Technology development for a rotary microfilter is well underway. Laboratory and bench-scale testing with simulated and actual Hanford wastes has been performed. Relevant pilot scale testing has also been performed on SRS wastes. Additional work has been conducted at the Oak Ridge National Laboratory and Idaho National Laboratory. However, technology development is needed to test a prototypic scale filter using simulated waste for the bounding range of Hanford tank waste.

Status – Construction of an advanced design, full-scale prototype for SRS will be completed in FY 2010. Testing with Hanford waste was initiated in FY 2010.

Technology Development Priority – High

Decision Points – 2012 Sodium management decision

– 2014 Supplemental treatment decision

Insertion Point – 2018 Supplemental treatment initiation

6.3.2.3.2 At-Tank Small Column Cesium Ion Exchange (transformational technology) – An at-tank SCIX process is needed to support the at-tank integrated system discussed above. Similar to the rotary microfilter, technology development for SCIX is well underway. Laboratory and bench scale testing with simulated Hanford wastes have been performed. Relevant pilot scale testing has also been performed on SRS wastes. Much of the technology development and engineering design has already been demonstrated for SCIX. However, the optimized/revised design and operation parameters need to be demonstrated for the SCIX system. Such a demonstration must use the spherical resorcinol-formaldehyde resin for Hanford tank waste, instead of the SRS crystalline silicotitanate resin.

Status – Radiation stability testing (resin degradation and flammable gas generation) and alternate eluant testing will be completed in FY 2010.

Technology Development Priority – Medium

Decision Points – 2012 Sodium management decision
– 2014 Supplemental treatment decision

Insertion Point – 2018 Supplemental treatment initiation

6.3.2.4 Aluminum and Sodium Management – The Hanford tank waste includes a substantial quantity of alumina sludge. The alumina sludge is to be dissolved (leached) to reduce the volume of waste to immobilize as HLW. Caustic leaching to dissolve aluminate will require adding large amounts of sodium hydroxide during the pretreatment process. The added sodium required for aluminum leaching greatly increases the volume of LAW glass, and limits the throughput in the WTP pretreatment and second LAW facilities. In addition, treatability studies have shown that the waste's high silica content, combined with the caustic needed to maintain alumina solubility, may generate aluminosilicate gels that could cause operational problems for the WTP and potentially require additional equipment maintenance and replacement. New technologies are required to mitigate the cost and schedule impact of the added sodium.

6.3.2.4.1 Lithium Hydrotalcite (LiHT) Process (transformational technology) – Removing the aluminum upstream of the WTP has potential to improve the cost and schedule of the Hanford tank waste treatment mission. One method to remove aluminum that has been chosen for further development and identified as a transformational technology is a LiHT process. This process would remove dissolved alumina from the tank waste and yield, as a by-product, recyclable sodium hydroxide that could be used for subsequent sludge dissolutions. LiHT process development is in the early stages, but an aggressive development schedule is needed to support the WTP mission.

Status – An engineering evaluation on the lithium hydrotalcite process was completed and report issued in December 2009 (RPP-RPT-42970, *River Protection Project Mission Analysis Sodium Management Evaluation*). Waste simulant tests were initiated in FY 2010.

Technology Development Priority – High

Decision Points – 2012 Sodium management decision
– 2014 Supplemental treatment decision

Insertion Point – 2022 Implement in aluminum removal facility

6.3.2.4.2 Electro-Chemical Caustic Recovery – This is another potential method for aluminum and sodium management. Ceramatec's ™ electrochemical caustic recovery technology separates sodium ions from supernate and reacts the ions with water to yield a recyclable caustic stream.

Status – A report was issued in 2009 documenting bench scale test results using simulated and actual tank wastes.

Technology Development Priority – High

Decision Points – 2012 Sodium management decision
– 2014 Supplemental treatment decision

Insertion Point – As soon as practical to support WTP Operations

Ceramatec is a trademarked product of Ceramatec, Inc., of Salt Lake City, Utah

6.3.2.4.3 Continuous Sludge Leaching – A continuous sludge leaching technology developed by Parsons Corporation of Pasadena, California, is another candidate technology to be used with either the LiHT and/or electrochemical caustic recovery processes. Continuous sludge leaching dissolves sodium aluminate in a heated reactor then passes it through a cross-flow filter to generate a solids-free supernate.

Status – Bench scale testing of the continuous sludge leaching was completed in 2008.

Technology Development Priority – Medium

Decision Points – 2012 Sodium management decision
– 2014 Supplemental treatment decision

Insertion Point – As soon as practical to support WTP Operations

6.3.2.4.4 Aluminum (Al) Solubility – A better understanding of Al solubility under typical WTP and tank farm operating conditions may result in needing to add less sodium, reducing the amount of LAW to be treated.

Status – Aluminum Solubility testing was initiated in FY 2010.

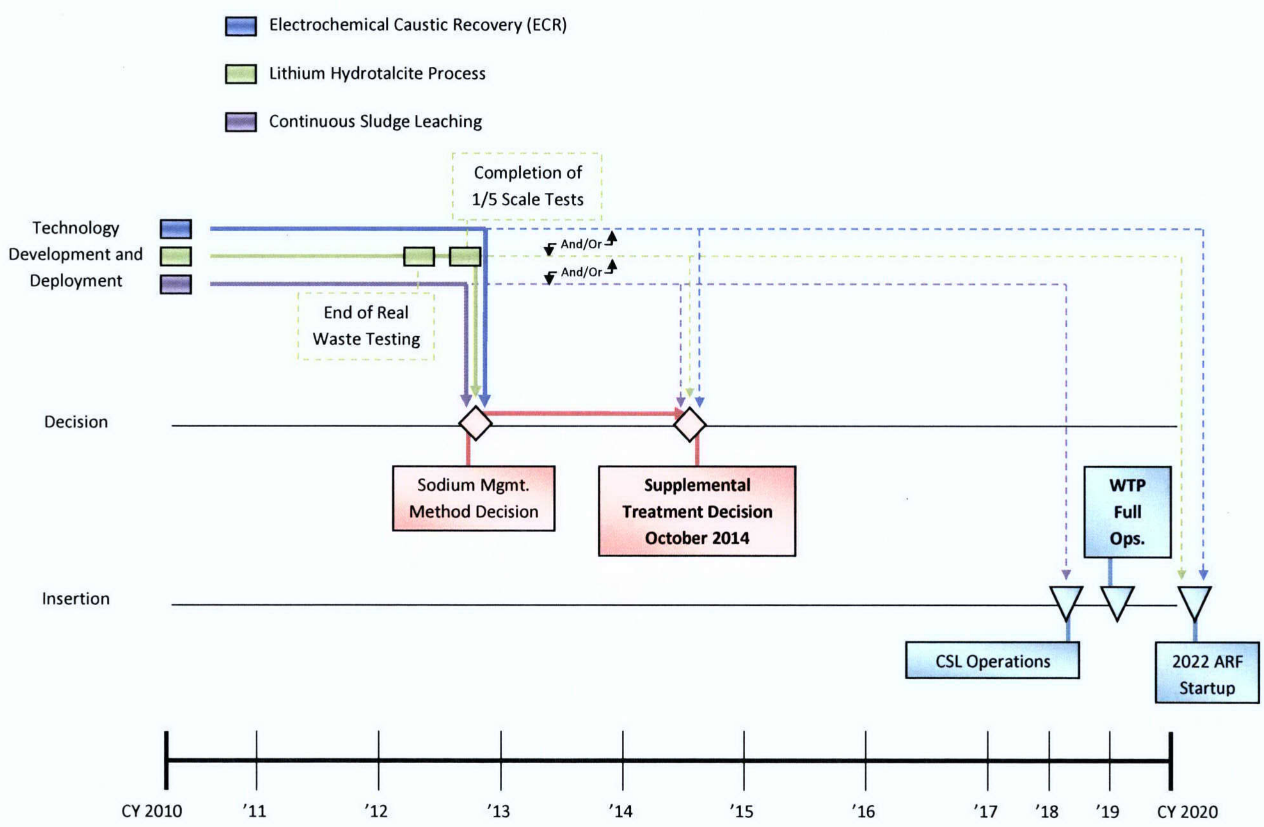
Technology Development Priority – High

Decision Points – 2012 Sodium management decision

Insertion Point – As soon as practical to support WTP Operations

TDD Timeline – Figure 13 depicts major TDD activities, decisions, and insertion points for aluminum and sodium management. At the end of FY 2012 an important decision will be made on which specific technologies to carry forward through deployment.

Figure 13. Sodium and Aluminum Management – Major Implementation Activities.



6.3.2.5 Supplemental Pretreatment – The WTP pretreatment facility is currently not capable of processing all of the LAW within the available operational period. Either the pretreatment facility's processing rate must be increased, or additional supplemental pretreatment processing capabilities must be developed and implemented. Supplemental pretreatment methods can improve the feed to the WTP (or alternate treatment methods) and address problematic waste constituents reducing processing cost and schedule. Tank waste components such as phosphates and sulfates can limit vitrification production rates at the WTP.

In addition, managing technetium 99 (Tc-99) is a concern. To limit discharge of Tc-99 into the secondary waste stream, a concentrated off-gas condensate is recycled within the WTP LAW vitrification process. This recycle, however, causes sulfur to build up in the LAW vitrification process. Rather than concentrating and recycling the off-gas condensate, the condensate could be discharged directly to the Effluent Treatment Facility (ETF). However, this method only shifts the

Tc-99 issue to the ETF. Supplemental pretreatment technologies may need to be developed to address these tank waste components.

6.3.2.5.1 Tank Waste Blending (transformational technology) – Waste blending would combine waste from different source DSTs to yield a WTP feed that reduces the amount of resulting HLW glass. Development is required to identify the combinations of specific tank wastes that yield the best blend compositions.

There are three methods of supporting waste blending: (1) develop a retrieval sequence that supports a reasonable blending strategy, (2) blend wastes within the DST system subsequent to SST retrievals, and (3) install a dedicated mixing and blending facility. All three methods could be developed simultaneously, but the dedicated mixing and blending facility likely exhibits the greatest promise for achieving optimal blending. The SST retrieval sequence is influenced by objectives that compete with optimum blending, including environmental risk reduction, early tank farm closure, WTP feed balancing, and resource leveling. Blending within the DST system is constrained by the limited DST space available early in the WTP mission. Nevertheless, these latter approaches are the least costly to implement.

Status – Numerous blending studies have been completed with the latest issued in December 2009 RPP-RPT-42968, *River Protection Project Mission Analysis Waste Blending Study*.

Technology Development Priority – High

Decision Points – 2011 Waste mixing, blending, and certification sampling facility (see Section 6.3.2.1) or blending in DSTs

Insertion Point – 2018 for mixing, blending, and sampling facility option or as soon as practical to support WTP operations for DST option

6.3.2.5.2 Phosphate Management – If the phosphate content in HLW melter feed exceeds an established maximum, it limits waste oxide loading in the glass. In addition, phosphate precipitation during transport can plug pipelines. Technology development is required to assess and develop phosphate management technologies.

Status – Phosphate management is currently being addressed through advanced glass formulations and waste rheology testing. Alternate candidate technologies will be identified and initial proof of concept testing will be completed in FY 2010.

Technology Priority – Low

Decision/Insertion Points – As soon as practical to support WTP Operations

6.3.2.5.3 Sulfate Management – Sulfate can limit waste loading in both the LAW and HLW melters. Technology development is required to assess and develop sulfate separation technologies.

Status – Currently being addressed through advanced glass formulations. Alternate candidate technologies will be identified and their potential performance assessed in FY 2010.

Technology Development Priority – Low

Decision/Insertion Points – As soon as practical to support WTP Operations

6.3.2.5.4 Technetium Management – Technetium is a long-lived highly mobile radionuclide in HLW that can volatilize in the melter. To avoid recycling Tc and the concurrent sulfur buildup, Tc management technologies need to be developed. Technologies under consideration include an improvement in technetium retention in glass and goethite precipitation from the off-gas condensate. However, current planning is to more effectively manage Tc at the ETF through enhanced stabilization of recovered solids or a Tc recovery treatment process such as ion exchange.

Status – A Justification of Mission Need to upgrade the ETF was completed in 2009. Approval of CD-0 was deferred until February 2011.

Technology Development Priority – Medium

Decision Points – 2012 Technetium management decision

Insertion Point – 2018 to support WTP Operations

6.3.2.5.5 Strontium (Sr) and Transuranic (TRU) Precipitation – Tanks AN-102 and AN-107 contain complexants that result in excessive quantities of soluble Sr-90 and TRU in the supernate. Technology development is required to remove the soluble Sr and TRU. An in-tank treatment process will precipitate these radionuclides from the supernate using chemical reagents such as sodium permanganate and strontium nitrate.

Status – Various laboratory tests have been completed in the past, but a specific technology has not been selected.

Technology Development Priority – Low

Decision Points – 2017 to support critical decision one (CD-1) for AN-107 in-tank strontium/transuranic precipitation.

Insertion Point – 2020 Initiate AN-107 in-tank strontium/transuranic precipitation

6.3.2.6 Alternative Waste Treatment – Current planning calls for a second LAW vitrification facility to process approximately two-thirds of the LAW. Three technologies for supplemental waste stabilization (bulk vitrification, steam reforming, and cast stone) have been identified in the

DOE/EIS-0391, *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*. While bulk vitrification and cast stone have been previously evaluated and discontinued, steam reforming is now being considered. In addition, some increase in the WTP glass production capacity (HLW and LAW) may be achieved with improvements in glass formulations and melter designs.

6.3.2.6.1 Steam Reforming (transformational technology) – The mission target of treating all tank waste by December 2047 is predicated on installing a second LAW facility. A technology that potentially could be deployed to provide all or part of the second LAW function is Fluidized Bed Steam Reforming (FBSR). The FBSR is a reforming/oxidation technology that uses a superheated steam-driven fluidized particle bed. The FBSR produces a dry granular material, which is an insoluble mineral that consists of several forms of leach-resistant aluminosilicates. However, the granular material must be macro encapsulated (grouted or otherwise immobilized) to yield a waste form suitable for disposal at the IDF. Waste form qualification for the final product must be performed with the intention of demonstrating that the FBSR sodium aluminosilicate product is "as good as glass" for immobilization of LAW. This product qualification is in the Program Planning and Test Planning phase, which will be concluded by the end of FY 2010. During the following two years, actual qualification testing will occur utilizing experience gained from current FBSR product testing and evaluation activities taking place at the Savannah River Site for treating Tank 48 waste.

The FBSR can also produce a soluble carbonate product, which would then require vitrification to complete the immobilization process. The benefit of this interim process step is that it reduces the waste volume below that of the retrieved tank waste.

Since 2001 a number of tests and experiments have demonstrated that FBSR is a viable candidate for interim and final processing of Hanford LAW. However, a particular difficulty with FBSR is scale-up. Even with carefully designed pilot plants, a scale-up can be difficult and may not reflect the experience in the pilot trial. A development effort to demonstrate the FBSR at the scale necessary for Hanford deployment is anticipated in the future. It has been proposed that bench scale testing commence during FY 2011. Beyond the initial testing, due to the scaling issues characteristic of the FBSR system, future test scope and schedule will be determined as appropriate and when possible. Implementation is scheduled for mid-2018 with the At-Tank Integrated Pretreatment System which includes microfiltration and cesium ion exchange.

> **Status** – Planning is underway to mature steam reforming and qualify the mineralized product to a point where deployment at Hanford could be initiated. Product qualification is in the planning phase, and testing will commence in FY 2011. System testing pre-planning is underway, and testing will begin in the near future.
>
> **Technology Development Priority – Medium**
>
> **Decision Points** – 2012 Sodium management decision
> – 2014 Supplemental treatment decision
>
> **Insertion Point** – 2018 Supplemental treatment initiation

6.3.2.6.2 Advanced Melter (transformational technology) – Glass production rates at the WTP will be limited by the current melter technology. Improvements in glass production rates and in waste loading may be achieved with improvements in melter technology. In addition to reducing the cost and schedule of waste treatment at the WTP, improvements in glass production rates would reduce the size of the planned second LAW facility or alternate treatment method.

There are two methods to implement improved melter production: (1) improvements to the current joule heated ceramic melter technology, including potentially higher operating temperatures and optimization of bubblers used for mixing, and (2) further development of a cold crucible induction heated melter.

Status – In FY 2012 a next generation joule-heated ceramic melter pilot test facility will be installed and integrated with components at the Vitreous State Laboratory of the Catholic University of America.

Technology Development Priority – High

Decision Points – 2017 Next Generation WTP Melter decision (JHCM or CCIM)

Insertion Point – 2024 First melter replacement

6.3.2.6.3 Advanced Glass Formulations (transformational technology) – Increasing the waste loading and overall throughput of the WTP through advanced glass formulations could also significantly reduce the cost and schedule required to treat the tank waste. Glass formulations need to be optimized while developing the next generation melter and waste blending methods to fully maximize melter throughput and minimize the quantity of glass generated. Advanced glass formulations may include improvements to borosilicate glass as well as investigation of phosphate glasses.

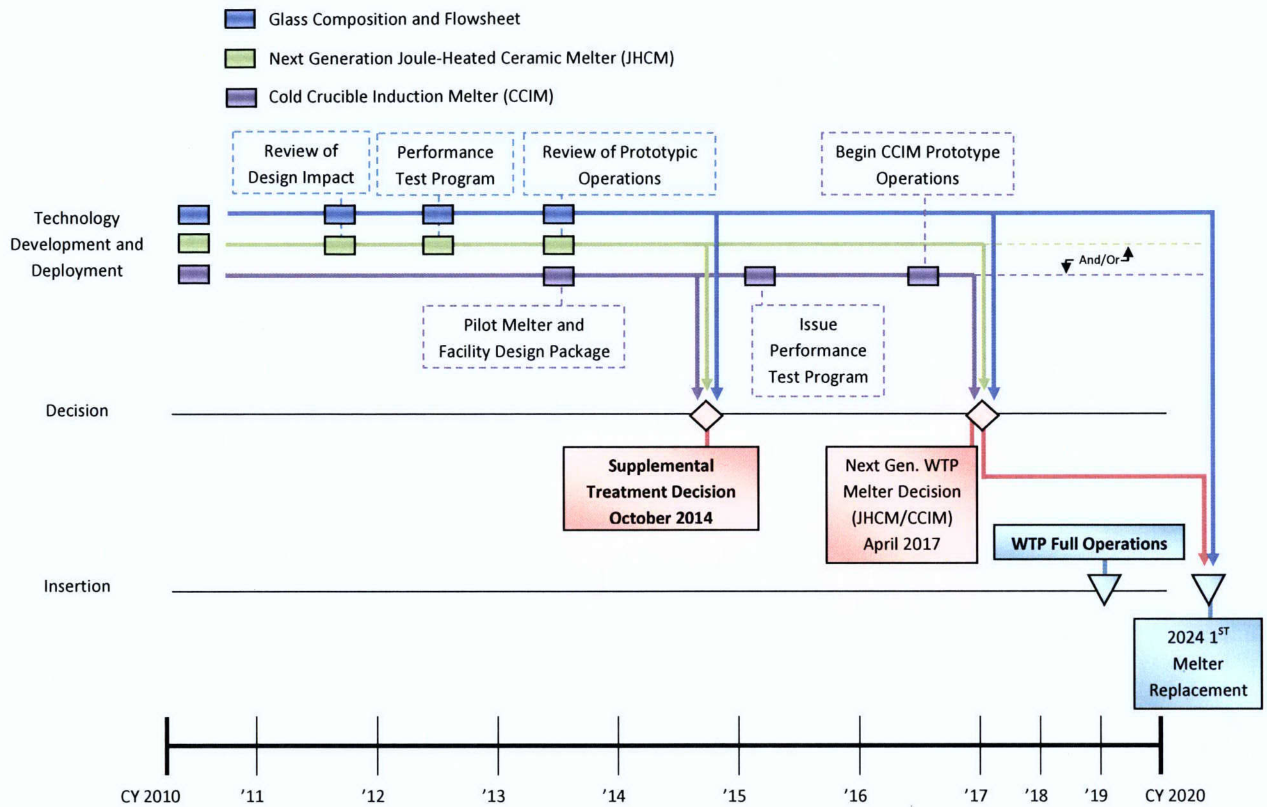
Status – The test facility at the Vitreous State Laboratory will be used to test improved glass formulations for potential use at Hanford.

Technology Development Priority – High

Decision/Insertion Points – As soon as an advanced glass formulation model is recommended.

TDD Timeline – Figure 14 depicts major TDD activities, decisions, and insertion points for designing, testing, and implementing the next generation melters and glass formulations. The major decision is to select cold crucible induction melters or joule-heated ceramic melters as the candidate for the 2024 WTP melter replacement.

Figure 14. Advanced Melters and Glass Formulations – Major Implementation Activities



6.4 TANK CLOSURE

When tank waste retrievals are finished, the SSTs will be closed according to TPA requirements, DOE orders, and National Environmental Policy Act (NEPA) requirements. Although tanks have been closed at other DOE sites, post-retrieval closure has not yet been performed at Hanford because an approved environmental impact statement record of decision for tank closure has not existed. It is expected that the SSTs will be closed after retrieval with a grouting process similar to that performed at other DOE sites. However, a specific method for closing the individual tanks, and each tank farm as a whole, has yet to be authorized.

Execution of tank closure activities in the field must wait for the Record of Decision for the DOE/EIS-0391, *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington,* to be issued. However, once tank closure is authorized several actions will be necessary including preparation of performance assessments, negotiating with regulators, and developing technologies to close Hanford tanks. The TOC must develop technologies to close both the SSTs and DSTs before or at the major activity mission targets identified in Table 6.

Note that soil and groundwater remediation is within the scope of CH2M Hill Plateau Remediation Company, not WRPS, and is therefore not included in this document.

Table 6. Tank Closure Goals.

Activity	Mission Target
Close C Farm	06/2019
Close all 149 Single Shell Tanks	01/2043
Close all 28 Double Shell Tanks	09/2052

Values taken from DOE 2009, ORP-11242, 2009, *River Protection Project System Plan ORP-11242*, Rev. 4, U. S. Department of Energy – Office of River Protection, Richland, Washington.

6.4.1 Tank Closure Technology Gaps (WP-2) and Opportunities

After tank retrievals are completed, residual materials in the tanks must be characterized and stabilized. To initiate closure activities, the waste volume, composition, and radionuclide content must be measured. Once a tank is ready to be closed, a cementitious material will likely be used to immobilize the residual waste within it. These characterization and stabilization methods require further development to gain authorization to begin closure activities.

6.4.2 Tank Closure Technology Solutions

6.4.2.1 Improved Residual Waste Characterization – Sampling and analysis tools and methods to assess the quantity, composition, and radioactivity of residual tank waste must be developed to understand the risks associated with immobilizing the waste in the tanks. Two technologies under consideration are Raman spectroscopy and radiometric characterization.

Status – Complete an in-tank detector design in FY 2010.

Technology Development Priority – Low

Decision/Insertion Points – As soon as possible to support tank closure when authorized.

6.4.2.2 Grout Formulations – Formulations of grout materials planned for tank closure may need further development. Although experience from past tank closure activities within the DOE complex provides some information, an understanding of additional grout properties is important to support the performance assessments.

Status – Grout formulations were successfully demonstrated in FY 2009 and further developmental actions are not planned at this time.

Technology Development Priority – Low

Decision/Insertion Points – As soon as possible to support tank closure when authorized.

6.4.2.3 Ancillary Systems Grouting Process – In addition to developing grout formulations, methods of adding the grout to tanks and ancillary systems (e.g., pits and transfer lines), may require additional development and testing.

Status – Processes for grouting tanks, pits, and transfer lines were successfully demonstrated in FY 2009 and further developmental actions are not planned at this time.

Technology Development Priority – Low

Decision/Insertion Points – As soon as possible to support tank closure when authorized.

6.5 TANK FARMS OPERATION

Operation of the tank farms includes minimum safe operations (maintaining the tanks/waste in a safe configuration). Minimum safe operations require monitoring waste within the tank farms and performing maintenance on equipment as needed. Technologies may need to be developed to enhance the efficiency and safety of performing work in the field (e.g., improved Industrial Health and Radiological Control monitoring).

In addition to developing new technologies to undertake tasks that cannot yet be performed, the TOC must improve efficiencies to tasks currently performed. The TOC must consider periodic infrastructure upgrades and improvements because aging equipment and systems deteriorate or their instruments and parts become obsolete. While not always recognized as a "technology development" need, evaluations of the service life of equipment, and plans for eventual upgrade, must be done.

6.5.1 Tank Farms Operations Technology Gaps/Opportunities

The ongoing interaction between the Technology and Development group and Tank Farms groups will likely lead to new technology development opportunities in the future that would support retrievals, pretreatment, or supplemental treatment within the tank farms.

7.0 REFERENCES

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APPENDIX A

TECHNOLOGY DEVELOPMENT SUMMARY MATRIX

Appendix A provides a TDR summary matrix. This summary matrix provides cross references between the technology gap or opportunity and the corresponding technical solutions. The summary matrix also links a technology solution to related documents. These documents include the Risk Management Plan; U. S. Department of Energy, Office of Environmental Management (EM-31) Engineering and Technology Roadmap, and Integrated Multi-Year Program Plan; and the National Academy of Sciences' (NAS) "Advice on the Department of Energy's Cleanup Technology Roadmap – Gaps and Bridges."

Table A-1. Technology Development Summary Matrix.

Technical Risk/Opportunity	Technology Gap Resolution	Technology Solution Development Activities	Decision/Insertion Points	RMP Mitigation or Opportunity Enhancement Strategies	EM-31 Roadmap / MYPP Strategic Initiative	EM-31 MYPP Sub-Level Initiatives	NAS Gap / Priority
Functional Area - Safe Waste Storage							
Tank waste must be safely stored in the SSTs and DSTs beyond their original design life.	Improved tank integrity tools and methods to provide tank leak and structural integrity confidence are needed.	Tank integrity tools and methods to assess the integrity status of the tanks and to provide information to plan the future use of tanks. Technology Priority: Medium	As soon as practical to support SST/DST operation and extended service life needs.	TOC-01 DST Space Management TOC-12 Tank Farm System and Infrastructure	1.1 Improved Waste Storage Technology	1.1.2 Improving Waste Tank Integrity Assessments 1.1.2.9 Tank Non-Destructive Examination 1.1.3 Improved Understanding of Tank Waste Chemistry and Behavior	N/A
Available DST space to support SST retrievals is minimal with the potential to halt outyear retrievals.	Improved methods of measuring waste behavior and gas retention are needed to maximize tank capacities.	New criteria and a measurement tool (cone penetrometer) are being developed to better characterize the buoyant displacement gas release event risk to allow use of additional DST space. Technology Priority: High	2012 planned deployment in tank AN-106 to avoid or alleviate DST storage space shortfall	TOC-01 DST Space Management TOC-02 SST Retrieval		1.1.1 Approaches for Increasing HLW Tank Capacity	
	Reducing the current waste volume provides additional space in DSTs and reduces the SST waste required to be stored.	A wiped film evaporator is being developed to allow local (near-tank) evaporation of tank waste reducing the volume of waste required to be stored. Technology Priority: Medium	2014 supplemental treatment decision (M-62-09-01) 2016 field deployment				
Functional Area - Waste Retrieval							
The ability to retrieve SSTs efficiently and effectively while minimizing water additions needs to be enhanced to support the SST closure schedule.	Develop more effective/efficient SST Retrieval Tools and Processes	Develop the Mobile Arm Retrieval System (MARS) to remove both bulk waste and sludge heels from sound and tanks assumed to have leaked. Technology Priority: High	2011 for sluicing mode demonstration during C-107 retrieval 2012 for vacuum mode demonstration during C-101 retrieval	TOC-1 DST Space Management, TOC-02 SST Retrieval TOC-04 Tank/Waste Management Area Closure Technology TOC-12 Tank Farm System and Infrastructure	1.2 Waste Retrieval Technologies	1.2.1 Develop a Suite of Residual Waste Removal Technologies	WP-1 High
		Chemical Cleaning (Acid/Caustic for heel dissolution) is being evaluated to assist with retrieval of the tank waste heels following bulk waste retrieval. Technology Priority: High	2012 sodium management decision 2011 for caustic cleaning demonstration during C-108 retrieval 2018 for oxalic acid cleaning demonstration during AX Farm retrieval			1.2.2 Develop Options for Chemical Cleaning	
		Develop in-tank elutriation methods to reduce risk associated with residual waste. Technology Priority: Low	As soon as practical to support SST retrieval and tank closure			N/A	
		Waste rheology - Slurry transfer studies and tests are needed to prevent the plugging of transfer lines and the removal of potential plugs. Technology Priority: Low	As soon as practical to support SST retrievals and waste feed delivery			1.2 – Waste Retrieval Technologies - Pipeline Unplugging 1.2.1.10 - Cross Site Transfer Mechanisms	WP-1 High WP-3 Med

Table A-1. Technology Development Summary Matrix.

Technical Risk/Opportunity	Technology Gap Resolution	Technology Solution Development Activities	Decision/Insertion Points	RMP Mitigation or Opportunity Enhancement Strategies	EM-31 Roadmap / MYPP Strategic Initiative	EM-31 MYPP Sub-Level Initiatives	NAS Gap / Priority
Functional Area - Waste Pretreatment and Stabilization							
Equipment and methods implemented within the tank farms to assist the WTP process could provide significant cost and schedule savings.	Pretreatment activities such as filtration and ion exchange performed within the tank farms could prevent the WTP Pretreatment facility from being the rate limiting component.	At-tank filtration using rotary microfilters as feed to the WTP Pretreatment Facility allows the liquid waste to bypass the WTP ultra-filtration system or feed an alternate LAW treatment system. Technology Priority: High	2012 sodium management decision 2014 supplemental treatment decision 2018 supplemental treatment commissioning	TOC-12 Tank Farm System and Infrastructure	1.4 Next-Generation Pretreatment solutions	1.4.1 Develop In- or At-Tanks Separation Solutions	WP-2 Med
		At-tank ion exchange would augment the cesium ion exchange capacity of the WTP Pretreatment Facility or feed an alternate LAW treatment system. Technology Priority: Medium	2012 sodium management decision 2014 supplemental treatment decision 2018 supplemental treatment commissioning				
	The steam reforming process can support a reduction in the waste volumes routed to WTP for processing.	Fluidized Bed Steam Reforming (FBSR) could allow waste to bypass the WTP by forming a qualified waste form for disposal at IDF. Waste form qualification will also be performed. Technology Priority: Medium	2012 sodium management decision 2014 supplemental treatment decision 2018 supplemental treatment commissioning	N/A	1.5 Enhanced Stabilization Technologies	1.5.3 Develop Supplemental Treatment Process	
	Advanced waste blending to improve WTP feed.	Tank waste blending prior to WTP feed will be further evaluated to reduce WTP HLW glass production. Technology Priority: High	2011 Waste mixing, blending, and certification sampling facility or blending in DSTs decision 2018 for mixing, blending, and sampling facility option or as soon as practical to support WTP operations for DST option	TOC-02 SST Retrieval TOC-12 Tank Farm System and Infrastructure	N/A	N/A	WP-3 Med WP-4 High
	Reducing the amount of sodium required to be added for aluminum leaching would greatly reduce the amount of immobilized LAW produced.	The Lithium Hydrotalcite process would remove dissolved alumina from the tank waste and yield, as a by-product, recyclable sodium hydroxide that could be used for subsequent sludge dissolutions. Technology Priority: High	2012 sodium management decision 2014 supplemental treatment decision 2022 for aluminum removal facility commissioning As soon as practical to support WTP Operations for other aluminum and sodium management options	N/A	1.4 Next-Generation Pretreatment solutions	1.4.2 Develop Improved Methods for Waste Separation	WP-2 Med
		Electrochemical Caustic Recovery - Ceramatec's ™ electrochemical caustic recovery technology separates sodium ions from supernate and reacts the ions with water to yield a recyclable caustic stream. Technology Priority: High					
		Continuous Sludge Leaching – CSL dissolves sodium aluminate in a heated reactor then passes it through a cross-flow filter to generate a solids-free supernate. Technology Priority: Medium					
		Aluminum Solubility Studies - A better understanding of Al solubility under typical WTP and tank farm operating conditions may result in needing to add less sodium, reducing the amount of LAW to be treated. Technology Priority: High					

Table A-1. Technology Development Summary Matrix.

Technical Risk/Opportunity	Technology Gap Resolution	Technology Solution Development Activities	Decision/Insertion Points	RMP Mitigation or Opportunity Enhancement Strategies	EM-31 Roadmap / MYPP Strategic Initiative	EM-31 MYPP Sub-Level Initiatives	NAS Gap / Priority
Equipment and methods implemented within the tank farms to assist the WTP process could provide significant cost and schedule savings.	Removal of waste components that limit solubility in glass to increase waste loading and throughput.	Development of a process to remove sulfate from tank waste to increase waste loading and reduce the amount of immobilized HLW produced. Technology Priority: Low	As soon as practical to support WTP operations			1.4.2 Develop Improved Methods for Waste Separation	
		Development of a process to remove phosphate from tank waste to increase waste loading and reduce the amount of immobilized HLW produced. Technology Priority: Low	As soon as practical to support WTP operations		1.4 Next-Generation Pretreatment solutions		WP-2 Med WP-5 High
	Technetium management technologies are needed to avoid recycling technetium.	Develop technetium management methods - includes an improvement in technetium retention in glass, goethite precipitation from the off-gas condensate, and treatment at the Effluent Treatment Facility through enhanced stabilization of recovered solids or a recovery process such as ion exchange. Technology Priority: Medium	2012 Technetium management decision 2018 to support WTP			1.4.1.3.4 - Technetium Ion Exchange	
WTP pretreatment doesn't possess the capability to process tank waste that contains complexed strontium and transuranics.	Develop in-tank techniques to precipitate complexed strontium and transuranics	Develop complexed strontium removal methods. Technology Priority: Low	2017 decision on in-tank treatment process for complexed strontium and transuranics 2020 to support AN-107 in-tank treatment	TOC-12 Tank Farm System and Infrastructure		1.4.1.3.7 - In-tank Strontium/Transuranic Removal	WP-2 Med
		Develop complexed transuranic removal methods. Technology Priority: Low					
The tank farms do not currently have the ability to provide the appropriate feed to the WTP.	The ability to adequately mix the sludge and supernatant waste within the DSTs and a sampling system to confirm WTP feed requirements have been met needs to be developed.	The ability to adequately mix the waste in the DSTs to meet the WTP acceptance requirements is being developed and demonstrated. Technology Priority: High	2011 Waste mixing, blending, and certification sampling facility or blending in DSTs decision 2018 for mixing, blending, and sampling facility option or as soon as practical to support WTP operations for DST option			1.4.1.9.1 Advanced Mixing Models	N/A
		The ability to sample the waste in the mixed DSTs prior to feeding to the WTP is being developed. Technology Priority: High					
The efficiency of the WTP process for producing immobilized waste could be improved on reducing the amount of ILAW and IHLW produced.	The glass formulations could be optimized to increase waste loading.	Improved borosilicate glass formulations are being developed to increase waste loading and reduce immobilized waste produced. Technology Priority: High	Decision on whether to proceed as soon as an advanced glass formulation model is recommended Implement as soon as practical after decision to proceed with implementation	N/A	1.5 Enhanced Stabilization Technologies	1.5.2 Develop Advanced Glass Formulations	WP-5 Med
		Investigate Phosphate glasses for glass waste loading, glass durability, and compatibility with existing melters. Technology Priority: Medium					

Table A-1. Technology Development Summary Matrix.

Technical Risk/Opportunity	Technology Gap Resolution	Technology Solution Development Activities	Decision/Insertion Points	RMP Mitigation or Opportunity Enhancement Strategies	EM-31 Roadmap / MYPP Strategic Initiative	EM-31 MYPP Sub-Level Initiatives	NAS Gap / Priority
The efficiency of the WTP process for producing immobilized waste could be improved on reducing the amount of ILAW and IHLW produced.	The joule heated ceramic melter technology could be optimized to increase throughput and waste loading.	Advanced LAW and HLW melter development is being performed with advanced glass formulations to increase waste loading and throughput. Technology Priority: High	2017 Decision on next generation melter for first melter replacement. 2024 1st WTP melter replacement	N/A	1.5 Enhanced Stabilization Technologies	1.5.1 Develop Next-Generation Melter Technology	WP-4 High
	Develop alternate melter technology	Investigate the use of a cold crucible induction heated melter as an advanced melter with potential for higher process temperatures and greater throughput. Technology Priority: High					
The immobilized LAW needs to be suitable for disposal in the IDF.	Perform required testing to qualify waste forms.	Glass and cast stone testing for IDF. Technology Priority: Low	Complete. No further testing planned.		1.5 Enhanced Stabilization Technologies	N/A	N/A
Functional Area - Tank Closure							
The SSTs are planned to be closed after retrieval. Methods for closing the individual tanks, and each tank farm as a whole, have yet to be defined.	Waste characterization techniques need to be developed to support closure decisions.	Develop improved residual waste characterization tools and methods. Technology Priority: Low	As soon as practical to support tank closure	TOC-03 Tank/Waste Management Area Regulatory Closure Process	1.3 Enhanced Tank Closure Processes	1.3.1 Improved Residual Tank Waste Characterization and Stabilization	N/A
	The grouting process required to immobilize the residual waste in tanks and ancillary systems needs development.	Develop grout formulations Technology Priority: Low	Completed	TOC-04 Tank/Waste Management Area Closure Technology		1.3.1 Improved Residual Tank Waste Characterization and Stabilization	N/A
		Develop tank and ancillary systems grouting process Technology Priority: Low	Completed	TOC-06 Tank Closure and Waste Management EIS ROD and Regulatory Approval Delay		1.3.2 Develop Materials and Technologies to Close Ancillary Systems	

DST = double-shell tank
EM-31 = U. S. Department of Energy, Office of Environmental Management
IDF = Integrated Disposal Facility
MYPP = multi-year program plan
NAS = National Academy of Sciences
RMP = risk management plan
SST = single-shell tank
TBD = to be determined
TOC = Tank Operations Contract
WTP = Waste Treatment and Immobilization Plant